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Prospects for Light-weight Aggregates

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This paper brings out overall and componentwise reduction in dead weights of a framed building when light-weight aggregates are used. It advances a case for their production in this country based on adequate cost analysis.

Introduction

Light-weight concrete is being increasingly used abroad for the last 10 years. Apart from its use in filler blocks, it is now being used as structural concrete. Considerable amount of research carried out has led to the formulation of two recent building codes (in USA and UK) for the use of light-weight structural concrete. As light-weight aggregates are not being produced in this country, the only choice before the engineer is to use stone/brick aggregate and bricks. A large variety of light-weight aggregates could however be produced from various industrial wastes resulting in a dual advantage of utilizing industrial wastes on one hand and making available new materials to the building industry on the other.

Light-weight concrete could be used in most of the building components, load bearing or otherwise. In general, where dead weight becomes a significant factor, as in the case of shell structures, folded plates, lift slab construction and prefabrication, light-weight concrete is the obvious choice. The use of light-weight concrete results in overall saving in the dead weight of the structure to the extent of 20 to 50 per cent. Componentwise breakups of the same are however not available. An attempt has therefore been made to analyse the weights and requirement of materials for a multistoreyed framed building, with a view to highlight the potential avenues for the adoption of light-weight concrete. This is followed by cost analysis of the traditional construction vis-a-vis light-weight construction. The permissible cost of the light-weight aggregates has been indirectly computed for no change in the total cost of both types of construction.

Basis of comparison

For comparison, a two-bay 20 ft span reinforced concrete framed office building is considered. A 12 ft column spacing is assumed in the other direction. For arriving at the sizes of columns, a six-storey structure is

envisaged. The slab, beam and columns are designed for a 50 lb./ft^2 live load. Specifications adopted for this study are as follows :

Traditional construction

(i) Dense concrete 1 : 2 : 4, (density 144 lb./ft^3) for slabs, beams, columns and footings; (ii) 9 in. thick brick masonry in 1 : 6 cement mortar for external walling and 4½ in. thick in 1 : 4 cement mortar for internal walling; (iii) Plastering in 1 : 6 cement mortar for walls and 1 : 4 cement mortar for ceiling; and (iv) 1½ in. thick Indian Patent Stone for flooring.

An analysis of the componentwise weights and superimposed loads indicates that the ratio of the superimposed loads versus dead weight of the component is highest (72 per cent) in case of slabs and lowest in case of columns and foundations (5.65 per cent). In beams, the share of the dead weight as compared to the superimposed load is small. This suggests that it is more advantageous to replace dense concrete with light-weight concrete in slabs than in the other components. From practical considerations, as in the case of Tee-beam construction, the beams also have to be of the same concrete as the slabs. Hence the following specifications have been adopted for the light-weight construction.

Light-weight construction

(i) Light-weight concrete, (density 100 lb./ft^3) slabs and beams and dense concrete, 1 : 2 : 4 (density 144 lb./ft^3) for columns and footings; (ii) Light-weight concrete, (density 80 lb./ft^3) hollow block masonry, 8 in. thick for external walling and 4 in. thick for internal; (iii) Plastering — same as for traditional construction; and (iv) Flooring — same as for traditional construction.

The above specifications are by no means for a complete house and only those items which have a bearing on the design of structural components have been considered.

Comparative analysis

Analysis of the weights and requirements of materials for both types of constructions indicate that the weight of the traditional construction is 4.8 times the live load, while that for the light-weight construction is 3 times. In other words, the latter is 37.5 per cent lighter than the traditional construction. The component-wise breakup of the design loads in a light-weight construction expressed as a percentage of loads in traditional construction shows the percentage reductions in design loads for slabs, beams and columns are 12.5, 31.9, and 32.2 respectively for the same applied live load. As regards the construction of essential materials, the light-weight construction will consume 22 per cent extra cement but will result in 22 per cent savings in steel.

The above figures may be taken as indicative of the trend with the use of light-weight concrete. A multistorey construction represents the modern trend in building industry. A typical cost analysis based on rates at Roorkee has been made for the traditional items of works in both constructions. The total cost of traditional construction works out to Rs 912.25 per 100 ft^2.

The cost of the traditional items in light-weight construction works out to Rs 531.38 per 100 ft^2 leaving Rs 380.87 towards the light-weight concrete items.

A typical cost comparison of common conventional items in both types of constructions shows the savings that result by the reduced dead weight of the structural members works out to Re 1 per sq. ft.

Cost computation

A typical computation of the cost of light-weight aggregates has also been worked out. Assuming Y as the cost of light-weight aggregates required to produce 100 ft^3 of light-weight concrete, its value works out to Rs 172.86 for equal cost in both types of constructions. Thus the corresponding average permissible marketable cost for the mixed light-weight aggregates (both coarse and fine) is Rs 117 per 100 cu. ft and based on prices prevalent in Roorkee. It is stated[1] that the cost of production of light-weight aggregates in this country is likely to range between Rs 16 and 35 per 100 cu. ft depending upon the raw material used for the manufacture of the aggregates. Thus assuming the marketable rate for the aggregates in the country will be around Rs 50/100 cu. ft the expected savings will be Re 0.88 per sq. ft in the example worked out. The influence of the cost of light-weight aggregates on the cost savings in a multistorey construction is also worked out for places where there is a possibility of manufacturing light-weight aggregates. The saving was greatest for Kanpur and followed in the order of Madras, Bombay, Bhilai, Delhi and Roorkee.

Conclusion

It can be concluded that the use of light-weight concrete results in the reduction of dead weight of the structure by 37.5 per cent. The saving in steel is of the order of 22 per cent while the consumption of cement would be 22 per cent higher.

The marketable cost of mixed light-weight aggregate for equal cost of construction, traditional and light-weight can be as much as Rs 119, 123, 157, 159, and 163 per 100 cu. ft for Delhi, Bhilai, Bombay, Madras and Kanpur respectively. Taking the marketable cost at Rs 50/100 cu. ft it can be seen that the savings range from Re 0.88 to Rs 1.48 sq. ft. Thus the prospects for the light-weight aggregate are bright.

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Manufacture of Aerated Concrete in India

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This paper puts forth a proposal for the manufacture of aerated concrete based on lime and fly ash. The technical know-how developed at this Institute has been reported together with the two important economical advantages, i.e. conservation of portland cement, a scarce material, and reduction in costs. Areas of collaboration with the industry have been outlined with a view to producing this product commercially with indigenous resources.

Introduction

Aerated concrete is one of the two classes of cellular concrete which can be produced by autoclaving a set slurry consisting of fine silicious materials and a binder and a high percentage of closed microscopic pores incorporated with the help of air-entraining or foaming agents. This type of material is already in use abroad because it leads to greater productivity in buildings, reduction in costs of transport of building materials to the site, reduction in foundation loads and consumption of building materials in a building. Its popularity can be judged from the fact that the world production has gone up by 50 per cent during the last 10 years and in UK, the production has risen from 0.05 to 0.9 million cubic metres[1]. The production of foamed concrete in India is about 0.15 million cubic metres.

The important binders used in aerated concrete are portland cement or lime or both. The Central Building Research Institute has done considerable work on foamed concrete with portland cement as binder and has the technical know-how.

Prospects of manufacture in India

Raw materials. A variety of siliceous fines can be used in manufacturing aerated concrete ; fly ash, granulated slag and quartz sand being the important ones. The former two are industrial wastes and the last mentioned is a naturally occurring material. Fly ash, the most important raw material, is a waste product of thermal power stations which, many a time, are situated in or near big towns. This is a happy situation both from the point of view of disposal of fly ash and nearness to a potential market. The availability of fly ash is indicated in Table 1.

Table 1—Availability of fly ash from the various thermal power stations

	Power Station	Capacity (M.W.)	Year of commissioning	Annual availability of fly ash (million tons)
1.	Bandel	4×75	1964/65	0.540
2.	Durgapur (W. Bengal)	60	Existing	0.074
		2×75	1963/64	0.270
		1×75	1965/66	0.135
3.	Durgapur (D.V.C.)	150	Existing	0.180
	Durgapur (D.V.C.)	140	1964/65	0.252
4.	D.V.C. Chandrapura	1×140	1964/65	0.252
		1×140	1965/66	0.252
5.	Patratu	2×50	1964/65	0.180
		2×50	1965/66	0.180
		1×100	1965/66	0.180
6.	Barauni	2×15	1962/63	0.036
		1×15	1963/64	0.018
		2×50	1965/66	0.180
7.	Trombay	62.5	Existing	0.103
		1×125	1965/66	0.175
8.	Korba	4×50	1964/65	0.360
9.	Amarkantak	2×30	1963/64	0.084
10.	Talcher	1×60	1964/65	0.108
		3×60	1965/66	0.324
11.	Ahmedabad	1×30	1962/63	0.032
12.	Kanpur	1×15	1962/63	0.016
		2×30	1964/65	0.084
13.	Madras	1×30	Existing	0.030
14.	Bokaro	295	Existing	0.203
15.	Delhi	1×30	1963/64	0.036
		1×15	1963/64	0.018
		3×60	1965/66	0.252

The physico-chemical behaviour of fly ash is dependent upon its unburnt fuel content, nature of mineralogical assemblages, glass content etc.[2] and as such is unpredictable from chemical composition alone. However, according to experience gained elsewhere[3], generally, fly ashes with low unburnt fuel, CaO and SO_3 contents are to be preferred. Fineness is another very important requisite. Pending a detailed examination of the suitability of different Indian fly ashes for the manufacture of aerated concrete, tentative conclusion can be drawn on the basis of the physico-chemical composition of the Indian ashes[2] and the work done[4] so far. The investigations show that Delhi, Durgapur and Bokaro fly ashes (river-side) can be used in the available form and that in other cases fractionation or grinding may have to be done. Alternately, the thermal power stations may have to make arrangements for tapping fraction of fly ash collected by the mechanical or electrical precipitators as this will contain a higher percentage of fine particles and a lower content of unburnt fuel.

A high quality lime, with CaO not less than 70 per cent and MgO not exceeding 2 per cent and a residue of not more than 5 per cent on 900 mesh sieve and not more than 25 per cent on a 4900 mesh sieve, is usually recommended for use[5]. There is no difficulty in producing lime to satisfy the above requirements. However, it must be emphasized that

quality of lime controls the quality of final product to a great extent. A lime of lower quality can result not only in lower strengths of the product but also can result in the bursting of the product.

Aluminium powder is the most common gas-producing agent used in the manufacture of this product and its quality also controls the final product. Generally high quality fine aluminium powder without any residue on 10,000 mesh sieve is recommended for use. Though suitability and efficacy of the indigenous samples require to be examined in details, one particular sample has been found to give good results.

Process technology. While general methods of production of aerated concrete are known, superiority of one product over another is believed to be due to some technological secrets. The latter can arise from differences in raw materials or processes. Nevertheless, since the building products are generally produced to satisfy minimum standards of strength and stability, development of a product of competitive quality is not considered a major problem. With a good knowledge of the raw materials and chemistry of the hardening reactions before and after autoclaving, schedules such as optimum proportions of raw materials, mixing, casting and autoclaving can be worked out in a laboratory. The CBRI has worked out a technical know-how of production of aerated concrete based on the Delhi fly ash and can undertake to work out technical know-how of production of cellular concrete based on slag, sand or any other raw material.

Plant and machinery. An outline of the manufacturing process is as follows:

The first step is mineral processing of raw materials which comprises crushing, grinding and sieving etc. This may also include a lime kiln if good quality lime is not available readily from the market. Similarly, a drier may have to be installed for drying silicious fines (i.e. fly ash).

The next step of proportioning involves equipment such as balances, feeders and water meters. Proportioning by weighing should be preferred and greatest control has to be exercised in the quantity of binder used.

For the process of mixing, mechanical batch mixers can be employed. Mixing of all the dry constituents and converting them into a slurry can either be done in a single mixer in three steps or alternately fly ash can be mixed with water into a tube mill to prepare a slurry which is then fed into a mixer to which binder and other additives are added in subsequent operations. The latter will lead to a greater efficiency and a better control of the product. In either case addition of binder should be done carefully and slowly so that it does not form lumps. Lime should be distributed over as large area of the mixer as possible and bottom of lime transporter should be opened very slowly. Consistency of the slurry can be adjusted with water before adding the gas generating agent.

The aerated mortar is fed into a distributing tank which feeds moulds arranged on a trolley. The moulds are stored and setting takes place in few hours time. Gas evolution should stop before setting of the mortar. The mould sides are stripped and the stiffened mortar is cut into slabs or blocks etc. with the help of cutting machines.

The next step is high pressure steam curing and plants required for this process are steam generators and autoclaves. According to Short and Kinniburg[6] autoclaves are frequently about 2.5 metres in diam. and more than 25 metres in length. The moulds remain in the autoclave

for about 14–18 hr at about 10.5 kg./sq. cm. pressure, the cycle of raising, maintaining and dropping of steam pressure to be fixed by trials. After cooling, moulds are taken out, stripped and the product is picked up for stock-piling.

Properties, scope and economics

Properties. Aerated concrete can be manufactured in a wide range of densities from 400 to 800 kg./cu. m. The corresponding strengths range from 14 to 49 kg./sq. m. For use in non-load bearing partition walls the minimum strength requirement is 28 kg./sq. cm. The aerated concrete based on lime-fly ash raw materials produced on a laboratory scale has shown dry densities ranging from 640 to 800 kg./cu. m. and compressive strengths from 30 to 56 kg./sq. cm. The modulus of rupture of the product was about 12.6 kg./sq. cm. The thermal conductivity, 'K' value, would be about 0.14 to 0.25 kcal./mh°C. The laboratory trials show that the product is comparable to that being produced abroad. The salient properties are reported in Table 2.

Scope of use. Aerated concrete has all the technical advantages of light-weight concrete which have been discussed elsewhere[7]. Because of its lightness, this material is ideally suitable for prefabrication and multi-storeyed constructions. It can be used as a walling material, either in the form of non-load bearing blocks or reinforced load bearing units. A high strength (63–70 kg./sq. cm.) can be used in constructions up to three storeys without structural reinforcement. Structural walling and roof units can also be produced for use in buildings.

Cost of production. Cost of production of aerated concrete proposed in this paper will be much lower than that of foamed concrete being produced in the country from portland cement and ground sand because of lower costs of the raw materials (lime and fly ash). The cost data in Table 3 show that cost of materials may be reduced by about 50 per cent. Since the machinery and process of manufacture are not likely to be much different, it is estimated that cost of fly ash based aerated concrete would be about Rs 60 against Rs 100 per cu. m. of cement based foamed concrete.

Table 2—Typical properties of trial aerated concrete

(Raw materials: Delhi fly ash, Dehra Dun lime, Aluminium powder)

(a) Average density	727 kg./cu. m.	(d) Moisture uptake from 99.9 per cent relative humidity at 27°–2°C.	6.50% by wt
(b) Compressive strength	57.92 kg./sq. m.	(e) Expected thermal conductivity	0.14 to 0.25 kcal./mh°C.
(c) Flexural strength	12.6 kg./sq. m.		

Table 3—Estimated cost of production of aerated concrete

(Capacity of plant, 50,000 cu.m. per year)

CAPITAL INVESTMENT	Rs	COST OF RAW MATERIALS	Rs	
Land	370,000	Fly ash	150,000	at Rs 5 per tonne
Buildings	450,000	Lime	500,000	at Rs 80 per tonne
Machinery & installations	3,300,000	Additions etc.	600,000	
TOTAL	4,120,000	TOTAL	1,250,000	

COST OF MANUFACTURE

Mixing autoclaving and labour etc.	Rs 1,700,000
Total cost of production for 50,000 cu. m.	Rs 2,950,000
∴ Cost of production per cu. m.	Rs 59

Collaboration with industry

While the CBRI can undertake to work out the complete technical know-how and also take up studies on pilot plant scale, cooperation from the industry would be welcome in the design and fabrication of equipment and machinery for a full sized plant of capacity of about 50,000 cu.m. per annum. No foreign exchange will be required as the entire machinery can be fabricated from indigenous resources.

Recommendations

There is a strong case for the manufacture of aerated concrete from lime and fly ash at suitable places in India. For implementing it the following recommendations are made :

(1) Technical know-how for any specific problem can be worked at the Central Building Research Institute.

(2) The building industry (specially Hindustan Housing Factory) should collaborate with the Institute in the design and fabrication of plant.

(3) A commercial plant of capacity of about 50,000 cu. m. should be set up with indigenous resources.

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Problems of Implementation of Building Research

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For the success of the implementation of the results of research, it is essential that the successful research projects must progress beyond the research laboratory through development, engineering and production stages so that a profitable sale of a product finally results. The success of the implementation of the results of research in building, however, depends not only on the above factors, but on long term tests, both in the laboratory and field conditions. The success and advantages of the application of any new technique, material or process could, therefore, be judged only after the building has stood for a period sufficiently long enough. As such, the results of research in building do not find their application at once. Further more, building industry being largely based on long standing traditions, techniques, materials, and processes generally followed, have deep-rooted effect on the minds of architects, engineers and builders and even the client himself.

The building industry itself remains very slow in its development on account of the lack of pressing demand and a certain amount of risks involved in the use of new methods and materials. Slower economic gains in the building industry as compared to other industries is also a factor affecting the speedy implementation. It is intended in this paper to enumerate the problems and difficulties encountered by the extension worker in the field of scientific extension of building research and to suggest ways and means to solve them.

Special features of building processes

A building is a more complex product than other industrial products as it involves the use of many different types of materials and components. The building industry, therefore, has two distinct branches to cater : (a) building materials, and (b) building techniques. The processes evolved as a result of research have, consequently distinct problems. The exploitation of building materials processes involves the problems of industrial production which depend on the availability of necessary machinery or a plant, while most of the building techniques, or engineering processes involve mostly better organization of labour and plant.

In many building processes, however, all the above aspects, i.e. the production of new materials, new components and new techniques may be involved. Examples are the use of light-weight concrete gypsum and various lignocellulosic fibrewastes. New techniques like prefabrication may involve the problems of transport and heavy lifting machinery. Hence, the engineering processes, are governed over and above the

availability of raw materials and the skilled labour, by local building research, and the climatic conditions also. The field of the implementation of the results of the building research, therefore, is much wider than other industrial products, and thus, need a much more coordinated approach on the part of the extension worker.

Motivation

Like all extension work, whether in education, agriculture, social uplift or industrial development, extension of the building research in the industry also depends first on the motivation. The motivation in the building industry may be either economy, speed of construction, use of substitutes for scarce or costly materials and increased efficiency in the building itself. The strongest of all these, perhaps is economy. The successful implementation, therefore, is largely or sometimes mainly governed by this factor alone.

It is a well-known fact that any new building process tends to be costly initially. Further, even if a particular process may prove economical in one region, and in certain conditions, the same may prove costlier in another region. It also takes longer for the building processes to establish its economy as the user gets convinced only when he becomes aware of its large scale successful application. The situation, could become more favourable if large state organizations like P.W.D. and large public sector undertakings would come forward first in the field of the utilization of the results of building research.

Favourable psychological background

For successful application of the results of research, a favourable psychological background is also essential. The greatest factor in this aspect is the safety and durability of the new structure. The best way of creating such a psychological background is the supply of test results to the parties concerned and to carry out full scale demonstration projects. In case of new building materials, the industry would also require to know where and how the new material could be used as the multiple usage of any materials would be a far more attractive proposition for the investor of the money than only a limited use. He may also feel shy of investment if there is no demand for new material; perhaps, this could be created by specifying new materials as an alternative material by the construction agency.

Raw material and means of production

While research workers do make an assessment of raw materials and other resources available in the country before taking up a research project, they may tend to assess only the total national resources available. They may also assume that certain plants and machinery required for a particular process, though, not available in the country could be made indigenously. However, the industry would always hesitate to venture the adoption of new processes unless a guaranteed long term supply of raw materials, and the availability of necessary plant and machinery is ensured. For example many of the CBRI processes like, particle boards from coconut husk, light-weight aggregate etc. have remained unexploited only on account of the non-availability of necessary machinery in the country. The machinery manufacturing firms perhaps may not come forth to invest money in the machinery required for building industry unless a

sizable market is ensured. This factor, therefore, becomes at times for more formidable hurdle to cross than even motivation and the psychological background. It requires, therefore, the fullest consideration both by the government and the industry. This difficulty could perhaps be solved by getting the necessary machinery by a special order with either the large government undertaking like Heavy Engineering, Machine tool plants or other private industrial concerns manufacturing heavy or light machinery.

Lack of skilled labour and artisans

The art of building, like many other crafts has hitherto remained traditional and hereditary. Acquirement of knowledge and the skill from father to son as in case of mason, carpenter and other crafts, is fast declining. The lack of availability of skilled labour and craftsmen is being experienced in our country even in the case of traditional methods and would get worsened in the case of new methods with the result that the new processes should always tend to cost more as compared to traditional methods. One of the reasons for such a situation is perhaps the lack of facility of training of this class of personnel which is so vital in the building industry. Perhaps it would be in the interest of the industry itself to take up the responsibility of creating such training facility all over the country.

Building by-laws and contract conditions

These are yet other bigger hurdles in the successful implementation of the results of building research. Since all building activity is restricted by local building by-laws, it would be very difficult to get the new techniques and processes implemented without their inclusion first in the codes of practices and the by-laws. Architects and engineers, reluctant to change from the known traditional and established practices, find a ready excuse for not utilizing the new processes. The industry would also come out and say that they are willing to adopt new processes provided architects and engineers first specify them in their designs.

The present condition of contract and the financial and other risks involved in the use of new processes would either make a contractor reluctant to undertake the work involving a new process or quote unreasonably high price to cover up the unknown financial and other risks. The construction authorities too while drawing up the contracts are reluctant to introduce new items in the absence of the availability of established rates, and would be quite unwilling to do the analytical work.

It is essential therefore, that this aspect is seriously considered both by the industry and the authorities concerned. Some provision like the insurance for covering up the risks involved in the use of new methods must be made in contract; similarly some provision must be made in the building by-law for the use of new processes.

Many agencies involved

There are a large number of agencies such as architects, engineers, builders, manufacturers and the clients involved in the building industry between the research scientist and the industry itself as compared to many other industries, where next to the research worker the manufacturer and the selling agency only would be involved. The manufacture of material

would further involve the selling and transport agencies. Thus, the results of the research in the building would find their successful implementation in the industry only when all the above agencies are fully satisfied and convinced about the advantages, economic or otherwise, offered by the new methods, material and techniques. A closer collaboration and contact between all the above agencies and the research worker and amongst the agencies themselves would not only improve the situation but is very much essential. The best manner in which such a collaboration can be achieved, is the joint consultation of problems at the designing stage itself, when the implementation of the use of new process would be properly thrashed out and all doubts cleared. Assurances about the soundness of the new process by an expert and experienced architect, builder or engineer would help in creating the necessary confidence.

Asbestos Cement Building Materials and the Problem of Import Substitution

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The accelerated pace of industrialization and housing arising from the various Five-Year Plans has created an unprecedented demand for building materials with the result there is an acute shortage of even basic construction materials like bricks, tiles, timber, cement, asbestos cement products etc.

The last named product, which was generally unfamiliar in this country some 35 years ago, has during the vicissitudes of World War II and the present Plan periods, proved itself to be an important building material—even like cement and steel. It is now almost impossible to think of any modern industrial establishment, housing or public works undertaking, without the use of asbestos cement in its construction.

Within its rather wide field of application, it is doubtful if asbestos cement products can ever be replaced by other substitutes. Modern sophisticated constructions in enlightened countries seem to prefer and are now finding more and more use for asbestos cement based products.

In our own country, the requirement of asbestos cement products has been increasing continuously, year after year. With the advent of emergency resulting from the Chinese aggression in 1962, the asbestos cement industry attained a position of strategic importance.

At present eight units are engaged in the manufacture of asbestos-cement products, the annual installed capacity aggregating to 4,54,000 tonnes as under :

(1) *Asbestos Cement Ltd*—Factories at : (a) Mulund (Maharashtra), (b) Kymore (Madhya Pradesh), (c) Calcutta (West Bengal), (d) Podanur (Madras) ... ... 2,00,000 tonnes

(2) *Hyderabad Asbestos Cement Products Ltd*—Factories at : (a) Hyderabad (Andhra Pradesh), (b) Ballabgarh (Bihar) ... 1,92,000 tonnes

(3) *Rohtas Industries Ltd*—Factory at : (a) Dehri-on-Sone (Bihar) ... ... 30,000 tonnes

(4) *Shree Digvijay Cement Co.*—Factory at : (a) Ahmedabad (Gujarat) ... ... 32,000 tonnes

The Directorate-General of Technical Development, Government of India, have estimated the demand for asbestos cement products at about 5.5 lakh tonnes per annum by the end of the Third Plan period, i.e. for 1965–66. To meet this projected demand, Government had suggested a capacity of 6 lakh tonnes per annum for the industry.

To fill the gap between the capacity of the industry and the projected demand, some fresh capacity and new ventures were licensed notwithstanding foreign exchange difficulties, as below :

Licensed Expansion

	Tonnes
(1) Asbestos Cement Ltd	36,000
(2) Hyderabad A.C. Products Ltd	60,000
(3) Shree Digvijay Cement Co.	36,000
	1,32,000

New ventures licensed :

(1) Southern Asbestos Cement Ltd	35,000
(2) P.R. Hede, Goa	36,000
(3) K.C.P. Ltd	30,000
(4) Bhagwan Industries Ltd	36,000
	1,37,000

It will therefore be seen that the industry's capacity which stood at 4,54,000 tonnes per annum at the end of 1963, has now been licensed to expand substantially to 7,23,000 tonnes per annum.

Government's action to license expansion with the full knowledge that the industry has to be supported with substantial imports of raw material despite the difficult foreign exchange situation in the country must have been reached only after a thorough investigation and study. This fully supports the view that asbestos cement is an important building material, very much needed for the economy of the country and no easy substitutes can be found.

The estimated asbestos fibre requirement to support a production of 7,23,000 tonnes per annum of asbestos cement products will be 69,000 tonnes, and in terms of foreign exchange would cost the country approximately Rs 7 to 8 crores.

Some facts about asbestos as it affects the resultant products

The 'Asbestiform' group includes 30 or more minerals of fibrous crystaline structure but only 6 or 7 have economic significance. These are in order of importance : Chrysotile, Crocidolite, Amosite, Anthophlite, Tremolite and Actinolite. Because it is superior to other types of asbestos for textile and other industrial purposes, generally chrysotile accounts for about 95 per cent of the total world consumption of natural mineral fibres.

From their chemical composition and certain physical characteristics, the asbestos minerals are broadly divided into two distinct groups :

A. *Serpentine Group*
Monoclinic
(1) Chrysotile
(2) Picrolite

B. *Amphibole Group*
Monoclinic
(1) Actinolite
(2) Tremolite
(3) Crocidolite

Orthorhombic
(1) Anthophylite
(2) Amosite

Table 1—Comparative tensile strengths

Type of material	Tensile strength (lb. per sq. in.)	Type of material	Tensile strength (lb. per sq. in.)
Ingot Iron	45,000	Rock Wool	60,000
Wrought Iron	48,000	Glass Fibre	1,00,000 to 2,00,000
Carbon Steel	1,55,000	Chrysotile Asbestos	80,000 to 1,00,000
Ni-Cr Steel	2,43,000	Amosite Asbestos	16,000 to 90,000
Piano Steel Wire	3,00,000	Tremolite Asbestos	1,000 to 8,000
Cotton Fibre	73,000 to 89,000		

Amongst all the varieties of fibres indicated above, chrysotile is most favoured for use in asbestos cement, as it has the best combination of length, strength, toughness and flexibility. Its resistance to alkalis is good. Table 1 gives comparative tensile strengths of various materials[1].

It will be noted that the strength of chrysotile asbestos is very high in comparison with tremolite variety in the amphibole group.

Asbestos cement in its numerous form is portland cement reinforced with asbestos fibres. Portland cement alone, while it is an ideal structural material when used in the form of a large solid block, is too brittle and rigid to be of any service in the form of comparatively thin sheets. When reinforced with asbestos fibres it can be converted into large strong flexible roofing units capable of carrying heavy loads. Although the asbestos fibre in asbestos cement sheets is ordinarily present to the extent of only 9–15 per cent, it so pervades the whole mass, not in the manner of the iron bars in ferro-concrete, but at a continuous mass of interlaced flexible and finely divided rods, that the resulting product has a tensile strength at least 10–15 per cent greater than the neat cement. The tenacious adhesion between certain grades of asbestos fibre and portland cement is such that it must be explained by 'pozzolanic' action. In fact there is evidence of the presence as loosely combined silica on the surface of asbestos fibres. The presence of fibre enables a sheet of cement only 3/16 in. thick to be handled easily in sizes up to 8 ft × 4 ft. It is impossible to conceive a sheet of similar dimension made up of, say, portland cement and sand to behave as well. It is equally not true that a satisfactory product can ever be made using asbestos fibres which have not the high tensile strength, flexibility, toughness and length of chrysotile fibres.

Asbestos mineral although in the form of hard rock can be split unlimitedly into extremely very slender fibres. The individual fibres of asbestos are so fine as to be below the limits that normal micros can resolve. Table 2 gives comparisions of approximate diameters of various fibres with chrysotile asbestos[2].

Certain aspects of manufacture of asbestos cement sheets

Manufacture of asbestos cement is simple in theory but is highly complicated in practice. Success or otherwise of the manufacture of the product depends on technological perfection in the matter of 'opening' the fibres, i.e. reduction of diameters of individual filaments without destroying their lenghths so that for a given weight of asbestos used, maximum distribution of interlaced fibre in portland cement matrix is achieved.

Table 2—Comparison of approx. diam. of various fibres with chrysotile asbestos

Type of fibre	Fibre diam. (in.)	Fibres in one linear inch
Human hair	0.00158	630
Ramie	0.000985	1,015
Wool	0.0008 to 0.0011	910 to 1,250
Cotton	0.0004	2,500
Rayon	0.0003	3,300
Nylon	0.0003	3,300
Glass	0.00026	3,840
Rock Wool	0.000142 to 0.000284	3,520 to 7,040
Asbestos—Chrysotile	0.000000706 to 0.00000118	850,000 to 1,4000,000

Generally asbestos cement sheets of desired thickness are made up with a number of thin laminations. A consequence of this method of manufacture is that the fibres tend to be drawn longitudinally into the line of flow of the machine with the result that a 'grain' effect is produced and asbestos cement sheets have a somewhat greater strength in one direction.

The laminated asbestos cement sheets are superior in many respects to non-laminated sheets made of asbestos cement slurry and compressed to the desired thickness and form. The plant and equipment used in many of the asbestos cement producing units in this country are based on 'Hatschek' wet machine process, i.e. manufacture of laminated asbestos cement products.

Research on Indian asbestos and its application to industries

Although the preliminary field surveys conducted so far have indicated the existence of chrysotile fibre deposits in the States of Bihar, Rajasthan, Andhra Pradesh and Mysore, further detailed exploratory work is still to be carried out of provide details as to the magnitude and quality of deposits in these areas. Since development of the indigenous chrysotile asbestos deposits for commercial exploitation will take some time, the asbestos cement industry will have to depend to a large measure on imports.

Geological investigation and field surveys have, however, revealed that there are abundant deposits of amphibole asbestos, mostly of tremolite variety. These fibres are weak and brittle and crumble easily.

A number of research institutions in this country have conducted a series of laboratory-cum-pilot plant tests to use amphibole fibres (tremolite variety) in the manufacture of asbestos cement. Some claim to have developed techniques and patented process for satisfactory utilization of these fibres, although this has yet to be fully proved as a commercially viable proposition. The process basically depends on 'opening' up of these brittle fibres by chemical reagents followed by a mild form of air agitation (as opposed to the rather rougher mechanical treatment meted out to chrysotile fibres) and use of very high pressures to consolidate the asbestos cement slurry into sheets of required thickness.

In the context that asbestos fibres are primarily used as reinforcing medium and such medium should possess high tensile strength, length,

flexibility and toughness to produce strong and satisfactory asbestos cement products, the claim that amphibole fibres — tremolite species which have none of these physical qualities — can be used in substitution of chrysotile fibres, either wholly or partly, throws overboard (a fact proved and accepted by all the asbestos cement producers the world over) the very basic concept of the need to use fibres to produce cement sheets.

It is also said that at least a good portion of chrysotile fibres can be substituted by amphibole fibres. This only means begging the question and admitting tacitly that the function of chrysotile fibres as a strength producing medium cannot be disputed. The use of amphibole fibres to admix chrysotile fibres will in effect only bring down the total effectiveness of the fibres to perform the functions for which they are provided and in the net result one can only expect asbestos cement material whose quality can only be far below that of acceptable standards.

The use of fibre blends consisting of varying quantities of chrysotile and amphibole fibres and production of laminated asbestos cement sheets and their consolidation by high pressures have also been suggested to overcome fall in strengths of the ultimate product resulting in the use of amphibole fibres.

Whilst use of intensive pressure may help to produce dense sheets, the wet sheets would lose their pliability an important characteristic without which it is almost impossible to mould sheets to the various profiles and contours without developing fissures or cracks at points where wet sheets are strained most while moulding.

It should also be pointed out that much of the experiments with the use of amphibole asbestos have generally been conducted on laboratory scale. The sheets produced have probably not been larger than 10 in. × 10 in. or 12 in. × 12 in. The flexure tests of some of these samples may have yielded comparable results close to the minimum requirements of relative standards to create certain amount of optimism, but in practice when asbestos cement sheets are produced on a commercial scale one aims to achieve strength of basic material to be at least 15–20 per cent above the minimum requirement, so that despite the vagaries of distribution of fibre filaments in general mass of portland cement, the average strength can never fall below the minimum standards.

Problems faced by the industry

In summary, it is observed that asbestos cement is an important building material for which no easy substitute can be found. The Government of India, in recognition of this fact, have thought it fit to license further expansion of the industry despite the foreign exchange limitations. Asbestos fibres are used in the manufacture of product as reinforcing medium and only chrysotile variety of asbestos fibre has the needed tensile strength, toughness and flexibility. These types of fibres have mostly to be imported as indigenous availability is at present very limited. Amphibole fibres — tremolite variety — though plentifully available, cannot be used in themselves satisfactorily on account of their lack of strength and flexibility. If the function of asbestos as a reinforcing medium is accepted, then satisfactory admixture of amphibole fibres with chrysotile fibres can only be accomplished by using better and costlier grades of fibre within certain limits or conversely the effectiveness of chrysotile fibres can be expected to be proportionally reduced.

The balance of trade and foreign exchange position of the country in recent years have been difficult. This has been further aggravated by the recent hostilities with Pakistan. Defence, food and their complementary industries have first claim over the meagre foreign exchange resources that are available. In the circumstances it is to be appreciated that little or no exchange may be available to import asbestos fibres and support even the existing installed capacity of the asbestos cement industry, let alone licensed expansions. An immediate and emergent action needs to be taken to substitute imports to the maximum extent possible. Some solutions to the problems are as follows : Currently most of the roofing sheets manufactured and accepted both by Government and Civil consumers are 9/32 in. (7.14 mm.) thick. Ours is the only country which produce and use this thickness of sheets. Most of the western countries produce only 1/4 in. thick sheets. If we follow this practice and maintain parity with the total area of roofing sheets produced at present, it should be possible for us to save approximately 8–9 per cent of the total foreign exchange needed to import the fibres. The Asbestos Cement Co. has recommended to the Govt that only 6 mm. thick roofing sheets should be produced which has been accepted.

The use of thin sheets would naturally involve extra purlins at reputed spacing of 4ft 6 in. instead of 5ft 6 in. for 9/32 in. thick sheets. This, however, should not present a serious problem.

The following two suggestions merit consideration :

(a) For limited applications like industrial housing projects, army barracks and other small structures, a part of the total roofing production may be in terms of light-weight standard corrugated sheets, size 2ft 6 in. wide × 1/4 in. thick. Only poorer grades of fibre are used in the manufacture of this type of sheets. Manufacture of these sheets, however, would involve foreign exchange to equip the existing industries with special templates.

(b) Purely as an emergency measure, slightly lower the quality standards so that slightly inferior fibre blends can be used and yet produce roofing sheets which are functional within practical safety factor required. This suggestion may appear to be a retrograde step, but the following simple workings show that re-appraisal of strength covered by ISI is probably admissible. For purpose of this working, the asbestos cement roofing sheet is treated as an equivalent to a freely supported beam.

The ISI[3] purlin spacing recommendation for 1/4 in. thick sheets is 54 in.

The minimum test load which a 1/4 in. thick sheet should withstand without breaking is 1245 lb. at 42 in. span, i.e. 30 lb. per in. width of a sheet.

Therefore, the minimum bending moment which the sheet will have to stand $= 1245 \times 42/4 = 13072$ lb. in.

In designing a roof the following loads are assumed to act in practice : (i) Wind load, (ii) Dead load due to weight of the sheet itself, and (iii) Weight of a full grown adult standing or walking on the sheet at mid span.

The wind load is approximately reckoned on the basis of 22.5 lb. per sq. ft normal to the surface of the sheet (resultant of a gale force of 100 miles an hour).

Conditions in our country do not generally need a roof slope in excess of 30° and in actual practice most of the roofs are designed for less. At

slopes less than 30° the wind load on rooflng sheets is actually 'negative' in character because of the suction effects of the wind[4].

Thus, the wind load does not cause any downward moment on the sheet span.

The dead load of a 1/4 in. thick sheet is approximately 3.5 lb. per sq. ft.

The weight of a full grown man is assumed at 200 lb.

Under the above assumed conditions, the maximum bending moment on a sheet supported at 54 in. purlin spacing resolves to :

Bending moment due to weight of sheet distributed uniformly and bending moment due to weight of man is equal to

$$3.5 \times \frac{54 \times 41}{144} \times \frac{54}{8} + 200 \times \frac{54}{4}$$

(where 41 in. is the width of the asbestos cement sheet)

$$= 363 + 2700 = 3063 \text{ lb. in.}$$

$$\therefore \text{ The factor of safety} = \frac{\text{Minimum bending moment the sheet should withstand (ISS requirement)}}{\text{Maximum bending moment under operating conditions}}$$

$$= \frac{13072}{3063} = 4.26$$

A factor of safety not more than 3 is normally adopted in R.C.C. designs, in spite of R.C.C. being a non-homogeneous material. A factor of safety, otherwise called ignorance factor, of a higher order than applied in R.C.C. practice need not be used in relation to asbestos cement roofing as most loadings are known and one need not provide a margin of safety for unforeseen loads.

One can perhaps safely adopt a figure for lower than 4.26, say 3. This slight reduction in transverse breaking load would enable the manufacturers to use whatever indigenous fibres that are available along with chrysotile fibres leading to a possible saving of 15 – 20 per cent in imported fibres.

Concluding remarks

It may be recalled by the original members of ISS Draft Committee 1955 (Building Divisional Committee 2:3) that a lower standard was suggested by some members to encourage the use of indigenous fibres. It was then felt that if the foreign exchange situation assumed serious proportions, a re-consideration of strength standards may be undertaken [Ref: Minute of 5th Meeting of Asbestos Sheets and Pipes Sub-Committee (BDC) 2 : 3 held on Sept. 13, 1965].

The present world demand for chrysotile asbestos, particularly the grades used in the manufacture of asbestos cement products, exceeds production. The position is further aggravated as a result of the recent political situation in Southern Rhodesia, which produces nearly 25 per cent of the world demand. India may find it difficult to obtain even her meagre requirements of these fibres regularly.

Even though there is a general agreed concept that amphibole fibres are unsuitable in the manufacture of asbestos cement, present-day conditions in the country make it imperative that continual research and development within the industry should be undertaken vigorously to find ways and means to use these fibres or find indigenous substitutes, e.g. glass fibre, rock wool, etc. to reduce the country's dependence on imported fibres.

For the past couple of years the Asbestos Cement Ltd has been experimenting with various types and grades of amphibole fibres. The results of recent experiments are very encouraging and we have every hope that we will find successful ways to use these fibres, partly in substitution of imported fibres in the manufacture of our products.

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Role of Soil Stabilization in Salt Industry

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Many salt works in India are facing the problem of percolation by which concentrated brine is lost through soil. Also the soft nature of soil does not permit the use of mechanical harvesters. This article reviews various methods of soil stabilization to increase the bearing strength of soil and to make the crystallizers impervious. The methods are : (i) compaction by applying static or dynamic load, (ii) mechanical stabilization by grading the soil by adding required aggregates, and (iii) chemical stabilization using lime, magnesium oxide, cement, bituminous materials etc. depending on the nature of soil.

With the growing demand of common salt in the salt based industries it has become necessary to modify and mechanize the salt works in order to increase the production, improve the quality of salt and produce salt more economically. Of the many factors influencing the salt manufacture, the nature of soil in the salt works and treatments given to it play an important role by affecting first the extent of salt production due to losses of concentrated brine by percolation through soil, and secondly the quality of salt by contamination of clay particles in the salt. Also very low bearing capacity of soil does not allow the use of mechanical harvesters.

In bigger salt works seasonal employment of large number of labourers for harvesting the salt poses a great problem. Moreover harvesting salt by manual labour takes much time which can be saved by using harvester and thus increasing manufacturing period. The basic need for the use of mechanical harvester is the stable soil below salt layer, which can withstand the load of harvester wheels without any appreciable settlement. Treatment of soil for increasing bearing capacity is needed for the salt works producing more than 50,000 tonnes of salt per annum where mechanical harvester can be used economically.

Percolation losses occur to a considerable extent in the salt works of Orissa, Andhra Pradesh and Madras and have to be reduced in every salt works irrespective of its size.

In marine salt works where seawater is starting material, the whole area of salt works is divided into three parts : first part called reservoir contains brine of 3–6°Bé; second, called condenser concentrates weak brine to 24° Bé and the third known as crystallizers which are meant for further concentration and deposition of salt, between 24° and 29.5°Bé. Soil of crystallizers is given special treatment. Volume of brine lost by percolation through reservoir and condensers may be higher than through crystallizers but relative amout of salt lost is less because of low density of brine in them.

Present method of preparing crystallizer beds is to puddle the soil in saturated state and then compact it by wooden rammers as the moisture content decreases by evaporation. Complete operation is done manually and takes about 2 weeks. In clayey soils this method gives almost impermeable beds but the strength of the soil in saturated condition is very low because of low dry density. On the contrary, sandy and sandy loam soils can give required bearing strength but lack imperviousness. Therefore the nature of both types of soils must be improved. Such improvement can be carried out by soil stabilization. The method and materials to be used in stabilization depend on the soil type and the improvement required. Therefore, it is not possible to state any definite process to prepare ideal crystallizers. After stabilization the permeability of soil should not exceed 10–3 cm./hr which corresponds to about 5 per cent loss of brine. It decreases as the salt layer accretes. Bearing strength of soil under saturated condition should be more than 1 kg./sq. cm. so that light harvesting machines can move on the salt layer without damaging the bed. To attain the required strength, soil should be treated in one of the following ways.

Compaction

Compaction is the cheapest, easiest and most economic method of soil stabilization and is being followed since early times. In the conventional method of preparing crystallizer beds, as the saturated soil losses moisture by evaporation, soil particles come closer and closer by tamping, and the dry density increases. Maximum density obtained by this method is between 1.12 and 1.28 g./cc. because of very less compaction effort. By using heavier rammers (e.g. 5 kg. iron rammer 50 cm. $\times$ 10 cm.), higher densities can be obtained. Increase in dry density obviously decreases void ratio, thus decreasing permeability also. Moisture content at the time of compaction should be optimum to get maximum dry density with least compactive effort. Laboratory studies are to be undertaken to find out optimum moisture content. Since the soil in salt works remains fully saturated throughout the season, compaction at moisture content above the optimum is advisable to decrease the tendency of swelling after saturation. Permeability of soil compacted to same density but at lower moisture than optimum is always higher than compacted at higher moisture content. Manually compacted crystallizers can be made hard by compacting the soil with iron rammers after compaction with wooden rammers.

Mechanical means of compaction are various types of rollers. Smooth wheeled steel rollers weighing 1–3 tonnes either bullock drawn or self propelled are suitable for compacting uniformly graded soils. Clayey soils resist compaction with smooth-wheeled rollers. For compacting clays, sheepsfoot roller of 1.5 ton weight is very suitable to obtain higher densities. Final levelling with smooth-wheeled roller is necessary in this case. Moisture control and density measurements are made after every four passes to establish minimum number of passes of roller.

Mechanical stabilization

Sandy soils even after compaction remain permeable and clayey soils lose their strength after wetting. It is due to the absence of all particle sizes in the soil. Soils of marine salt works are alluvial and are usually poorly graded. Such soils are stabilized by adding appropriate percentage of aggregates which they lack. Clayey soils require gravel-sand mixing and sandy soils require clay to stabilize them. Such method of increasing strength is called mechanical stabilization. The principle behind it is to

have particles of all sizes ranging from gravel to clay in uniform proportions. Coarse aggregates (sand-gravel) increase the strength through their frictional force between individual particles and clay acts as a binder. Silt and fine sand act as fillers to increase the dry density and decrease void ratio. Compaction at optimum moisture content is carried out after mixing the aggregates in soil.

Actual percentage of aggregates to be mixed depends on soil texture and minimum required strength and permeability. Many methods are available to find out minimum percentage of aggregates to be added. They depend on the sieve analysis of soil and aggregates.

Chemical stabilization

Many chemicals like lime, cement, magnesium oxide, bituminous materials, resins, have been reported as good stabilizers for road subgrades and foundation purposes. Their utility in salt manufacture is yet to be established. Lime, added to the soil to the extent of 3–5 per cent stabilizes soil. It reduces the plasticity index of soil and thus makes it more workable for compaction. During curing period it forms calcium carbonate which acts as a binder. Some calcium ions enter the crystal lattice of the clay mineral. These three processes help to increase the strength of soil. Magnesium oxide mixed with lime in molar proportions also increases soil strength.

Cement, when mixed and compacted at optimum moisture content with the soil increases strength. The reaction mechanism is not known. Minimum percentage of cement required varies with soil texture, sandy soils require less amount (5 – 10%) clayey soil more (15 – 20%).

Bituminous materials have binding and water proofing action on the soil. Lime-bitumen mixtures have been proved excellent for stabilizing black cotton soils. It may prove sucessful in salt works also.

Stabilization procedure to be adopted for reducing percolation losses firstly depend upon the soil type and secondly on relative cost of different stabilizers available at site. Wherever percolation losses are felt exact assessment of the salt lost is carried out to know whether the cost of stabilization exceeds the losses suffered by percolation. In case it does not exceed, a suitable method is selected which can stabilize the soil economically. Similarly, for the use of mechanical harvesters a comparative study should be made between the advantages and disadvantages of manual and mechanical harvesting of salt.

To summarize, compaction alone should be tried first to reduce percolation and increase strength. Addition of gravel, sand, clay or chemicals increases the initial capital investment but must be considered and undertaken when compaction does not give required properties. The exact treatment required has to be determined for different types of soils. Such studies are undertaken in the Institute.

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Shock Resistant Design of Structures

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The Earthquake School is actively engaged in research in connection with the design of various types of structures subject to shock loading like that due to earthquake, blast, impact, machine vibration etc. The School has tendered technical advice and in some cases, prepared the actual designs of residential buildings, industrial buildings like cement factory, steel factory, oil refinery, water towers, chimneys and machine foundations. For the solution of most of these problems, Digital Computer Programmes have been prepared. Quite often using such programmes, it will be possible to arrive at optimum design for various structures. The more important works carried out by the School are briefly described here.

Design of masonry buildings for earthquake forces

Tests on single-storeyed brick house models have been carried out under horizontal load condition. The models were reinforced in various ways such as (a) provision of horizontal reinforced concrete or reinforced brick work bands at lintel and slab levels, (b) use of vertical steel at the corners of buildings, junctions of walls and periphery of openings in the walls or a combination of (a) and (b). The results of the tests clearly indicated the efficiency of the verious types of reinforcement. It was found that vertical steel at the corners and junctions of walls constitutes the most efficient use of reinforcement. This result necessitates changing the practice of providing horizontal bands followed so far. This idea was presented at the World Conference in Earthquake Engineering earlier this year and was appreciated. Consequently technical advice has been tendered for the construction of masonry building at Heavy Electricals, Hardwar; Antibiotics Project, Rishikesh; Madan Mohan Malviya College at Gorakhpur; the City Board, Saharanpur; and the Fertilizer Corporation of India, Namrup, and all organizations handling defence construction in Northern India. It is hoped that it would result in great economy in the long run through cutting down losses during earthquakes.

These results are being incorporated in the ISI Code on the subject.

Reinforced concrete elevated water tanks

Elevated water towers fall in the category of those structures which are always important and of even more post-earthquake importance because generally fires break out during an earthquake due to leakage of gas or electric currents etc. and water is urgently needed for putting out such fires. A thorough study of the water towers including the staging and the

foundations has been made at the School and certain principles have been arrived at which would make the design safe against earthquake forces or other vibratory effects economically. Such principles include tapering of the staging, taking the foundation deeper, making foundations annular and installing mild steel diagonal braces in the staging panels. Organizations like Defence ; Jumna Valley Projects, Punjab Govt ; Heavy Electricals, Hardwar ; Gannon Dunkerly and Co.; Joseph Ellen & Co.; and the Antibiotics Project, Rishikesh, have been advised on the aseismic design of such water towers. Some water towers have already been constructed on the basis of these findings.

Period and damping measurements of several elevated water towers have been made in the Delhi and Roorkee areas. Results are being processed to have better correlations between theoretical and experimental results for further improvements in design. Test on a scale model of the water tower has been made on a vibration table at various levels of stresses to get a complete picture of the behaviour of water towers under earthquake conditions up to ultimate stage of loading.

Reinforced concrete buildings

A detailed study of multi-storeyed reinforced concrete frames has been made theoretically, including the effect of the joint rotation on their analysis. A scale model of such a framed building has also been tested on the vibration table. The results of such studies are being incorporated in the IS : Code 1893 'Recommendations for Earthquake Resistant Design of Structures' so that they could be adopted in general design practice. Organizations like PWD Assam, Shalimar Tar Products Ltd, and Defence department have been advised on the design of certain buildings on the basis of this work.

Factories

The school has tendered technical advice on the earthquake resistant design of civil engineering structures in paper factories at Darbhanga and Titagarh Cement Factories at Cerrapunji and Mirzapur, Bokaro Steel Plant, Oil Refineries Gauhati and Barauni etc. The problems of the factories are general of varied nature requiring every time a special theoretical or experimental study.

Foundations

The problems that are being studied at the School in this are the design of machine foundations for vibratory loads, pile foundations subjected to horizontal-static as well as dynamic-loads and the liquefaction of loose sands when subjected to vibratory forces. Some problems referred to the School regarding the foundation design are as follows:

(a) A reinforced concrete circular bin resting on piles about 80ft long for the CPWD.

(b) Foundations of an earth dam on river Bansas for the Gujarat State PWD where it was suspected that the sand may liquefy under the foundation due to earthquake forces.

(c) Tests were made on the Qutab Minar which has tilted one side to find how earthquakes will affect its safety. Certain studies on the foundations and the structures have been recommended.

(d) The behaviour of the vibration characteristics of the compressers of a fertilizer factory are in hand and work on another factory is to begin soon.

(e) Technical advice has been tendered to M/s Dastur and Co., on the specification for the Bokaro Steel project for design of structures against earthquake forces and also on the design of forge hammer foundations.

(f) Isolation of the factory for electric instruments owned by Joseph Ellen and Co. against the vibrations transmitted by a forge hammer.

Dams and power houses

The School has undertaken a theoretical and experimental study of earth dams with regard to stability of upstream and downstream slopes; the type of impermeable core to be provided, and the behaviour of foundations.

Some of the more important work is described below :

(a) Seismic stability of Foundation of the Obra Dam : The vibratory tests were performed on models to determine the liquefaction and settlement characteristics. The design of the dam is being modified according to advice tendered and other measures suggested in the advice are being adopted.

(b) Seismic stability of the Ramganga Dam and Saddle Dam Blast studies were carried out at the dam site to determine the pertinent soil constants and seismicity of the site. A scale model of the Ramganga Dam was tested on a large size shock vibration table and the significant conclusions arrived at regarding the variation of the relative acceleration pattern on the height of the dam, and the greater effectiveness of the inclined core were under consideration of the Control Board.

(c) The seismic stability of Kothar Dam is under study.

In addition to the above, technical advice was also rendered to Central Water and Power Commission about the feasibility of constructing high dams in seismic zones, on the design of Tennughat Dam in Bihar and on the design of Berna and Tawa dams; to Bhakra and Beas dam projects regarding the design of Beas dam intake structure for tunnels ; and to U.P. Irrigation Department on the seismic factor for the design of an underground power house in the Yamuna Valley Scheme.

Blast resistance

Advice was tendered to Bhakra Control Board on the advisability of blasting near the dam at the time of the failure of Hoist Chamber.

Studies were also made on the downstream retaining walls of Bhakra dam cracked due to excessive vibrations.

The problem of exhaust blast from jet planes acting on hangers, water towers and other structures is being studied for defence department.

Conclusion

From the above it will be seen that the School has been keeping itself in close touch with the problems that arise in the design of various types of structures in the industry, the State and Central Governments, the Defence

Organizations and in the various private and public undertakings. The School has equipment for dynamic measurements and trained personnel to take up the work of design for vibratory forces. It will, however, be necessary to strengthen the already existing facilities in certain areas to enable the School to handle any problem involving structural and machine vibrations. The School, which is 5 years old, has contributed substantially to the development of design practice for earthquake resistant construction and its services have been used particularly by Defence and Irrigation Departments and a large number of industries.

CMERI Research on Industrial Structures

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The economical structures developed at CMERI bring down the cost of industrial structures such as factory sheds, workshops storage sheds, etc. and cut down the time to put up such structures. Adoption of these structures by the industries on a national scale could result in saving of several thousand tons of steel making an effective impact on country's economy. The pace of industrialization could be stepped up by the speed with which these structures are put up. The research conducted on developing these built up joists opens up a new field of great economic value in structural design.

Introduction

The shortage of raw materials and the difficulty in importing them on account of the serious foreign exchange scarcity is a great deterrent for the industrialization programme. Steel is one of the basic raw materials and is in short supply. Maximum economy in the use of steel is therefore a must so that foreign exchange spent on import of steel and investment needed for increasing steel capacity is kept to a minimum.

The pace of industrialization depends to a great extent on the speed with which factory structures are put up. Most of the projects in India are suffering because of delays in the schedules of erection of structures. These delays have occurred either due to nonavailability of suitable steel sections or due to an overall shortage of steel in the country.

With a view to effecting economy in structural steel by reducing the weight of the structure and also to develop methods of easy and quick fabrication and erection, research on light-weight steel structures started at CMERI.

The tension field-web beams, open-web beams, and cold formed beams made from thin sheets are the three main types of members used in light-weight construction. The CMERI chose to work on open-web beams of lattice construction using easily available angles and round bars. The section parameters are designed on the basis of optimum strength against weight of steel used. This resulted in a most economical and light-weight section compared with all the existing sections including the open-web castella section. Besides being the most economical type of section produced so far, the easy availability of angles and bars removes one of the big bottlenecks in India today in procurement of suitable sections for structural fabrications.

Pitched portals made up of these open-web joists are used in redesigning a factory shed of 16 metre span, and 9.5 metre height to eaves level. A saving of 43 per cent in steel by weight was achieved over a conventional design replaced. The CMERI has erected a 16 m. × 24 m. shed to this design. A twin bay storage shed of Heavy Electrical Ltd, Bhopal was next designed by the CMERI method. A saving of 63 per cent was achieved over a conventional design of B.H.E.L., Hyderabad, for the above storage shed. Similarly the CMERI design worked out for Kumardhubi Engineering Works structural shop yielded a 47 per cent saving over their conventional design. Numerous design works employing the CMERI methods for various industries are now in progress. An interesting exercise made in replacing a tabular truss of 44 ft span given in NCAER's report on 'Saving in Structural steel through Standardization' by CMERI design of open joist construction showed a saving of 27 per cent by weight of steel.

Model tests carried out on a pitched portal of 160 cm. span and 95 cm. height to eaves level indicated that the stresses developed in the structure were well below the calculated values showing thereby considerable reserve and margin of conservatism in the calculated values obtained with the formulae used in developing CMERI structures.

Analysis

The analysis is made on the following assumptions :

1. The web bracing carries the shear force S in diagonal tensions only.

2. The web bracing does not appreciably contribute to the area and moment of inertia of the section.

3. Secondary stresses on the web bracings and flanges are negligible.

4. The portal is hinged at the ground support.

The bending loads are carried by the flange elements and the shear load in diagonal tension by the web bracing, and the corresponding bending stress and diagonal tensible stress are obtained* as :

$$\sigma_b = \frac{M}{2nDtb(1+k)} \qquad \ldots(1)$$

and
$$\sigma_t = \frac{4T}{D^2} = \frac{4S\cos\alpha}{\pi D^2} \qquad \ldots(2)$$

Taking the appropriate allowable stress values for σ_b and σ_t and the maximum values of M and S we have :

$$(\sigma_b)_w = \frac{M_{\text{max.}}}{2NDtb(1+k)} \qquad \ldots(3)$$

$$(\sigma_t)_w = \frac{4S_{\text{max.}}\cos\alpha}{\pi D^2} \qquad \ldots(4)$$

Eqs. (3) and (4) are the governing equations in the design of open-web joist sections.

The maximum bending moment and the maximum shear force for the beam subjected to a concentrated load P are given by :

$$M_{\text{max.}} = \frac{PL}{4} \qquad \ldots(5)$$

*For details refer to CMERI, Durgapur.

and $S_{max.} = P/2$ ...(6)

Substituting Eqs. (5) and (6) in Eqs. (3) and (4) we get:

$$(\sigma_b)_w = \frac{PL}{8nDtb(1+k)} \qquad ...(7)$$

$$(\sigma_t)_w = \frac{2P\cos\alpha}{\pi D^2} \qquad ...(8)$$

The maximum bending moment $M_{max.}$ and the maximum shear force $S_{max.}$ for the portal subjected to a wind loading are obtained as:

$$M_{max.} = \frac{3Ph}{2} + \frac{3(B+K)}{4A} PL\cos\theta \qquad ...(9)$$

$$S_{max.} = \frac{3P}{2}\left[1 + \frac{2h\cos\theta}{L} + \frac{(B+K)}{A}\cos^2\theta - \frac{\sin 2\theta}{2} + \frac{(B+K)(1+4)}{2A}\sin 2\theta\right] \qquad ...(10)$$

The frame constants A, B and K are described under Nomenclature.

Substituting the above values in Eqs. (3) and (4) we get:

$$(\sigma_b)_w = \frac{1}{2nDtb(1+k)}\left(\frac{3Ph}{2} + \frac{3(B+K)}{4A} PL\cos\theta\right) \qquad ...(11)$$

$$(\sigma_t)_w = \frac{6P\cos\alpha}{\pi D^2}\left(1 + \frac{2h}{L}\cos\theta + \frac{(B+K)}{A}\cos^2\theta - \frac{\sin 2\theta}{2} + \frac{(B+K)(1+4)}{2A}\sin 2\theta\right\} \qquad ...(12)$$

Minimum weight considerations

Design of any structure for minimum weight is essentially based on the determination of optimum proportions for the simultaneous failure conditions occuring in all the critical modes. A structure of least weight is obtained by minimizing the weight function subject to these simultaneous failure conditions.

For the simultaneous material yielding in flange and web at the applied load P.

$$\frac{PL}{8nDtb(1+k)} = \frac{2P\cos\alpha}{\pi D^2} = \sigma_y \qquad ...(13)$$

Minimizing the area of the section subject to the restraining condition Eq. (13) by introducing a Lagrange Multiplier λ leads to the variational equation:

$$\delta(A+\lambda\phi) = 0 \qquad ...(14)$$

where A is the area of the material in the cross-section and ϕ the restraining condition. The restraining condition ϕ is expressed as:

$$\phi = \sigma_b - \sigma_t = 0$$

$$= \frac{PL}{8nDtb(1+k)} - \frac{2P\cos\alpha}{D^2} = 0 \qquad ...(15)$$

Differentiating with respect to b and D

$$\left.\begin{aligned}\frac{\partial A}{\partial b}+\lambda\frac{\partial \phi}{\partial b}=0\\ \frac{\partial A}{\partial D}+\lambda\frac{\partial \phi}{\partial D}=0\end{aligned}\right\}\quad \text{...(16)}$$

Substituting for the derivatives of A and ϕ in Eq. (16) and solving for b and D we get:

$$b=0{\cdot}131\frac{L}{nt(1+k)}\sqrt{P/\sigma_y \cos\alpha} \quad \text{...(17)}$$

$$D=0{\cdot}798\sqrt{P\cos\alpha/\sigma_y} \quad \text{...(18)}$$

For design purposes, the limiting stress σ_y is replaced by allowable stress σ_w in Eqs. (17) and (18). Taking a typical example where P is equal to, 8500 kg.; L, 9·5 m.; t, 10 mm.; α, 45°; k, 1; n, 18; σ_w, 1500 kg./cm.^{2}; the section parameters are computed and a weight comparison is made with an equivalent rolled joist section ISMB 450X A40 per cent saving in weight is obtained over the rolled section. The results are given in Table 1.

In Table 2 are given the weight estimates of a shed of 16 metres span and 24 metres length consisting of four portals with CMERI design of box purlins and a comparison is made with the weight of a conventional shed of the same specification. An overall saving of 57 per cent is achieved in the optimum design. It is to be stressed that all the CMERI designs meet with the Indian Standards Specifications in every respect.

Table 3 gives the weight estimates per square feet of covered area for a tabular truss of 44 feet span and for a truss of same span made out of open web joists. A saving of 27 per cent by weight was achieved by replacing the tubular truss by the open web joist construction.

Discussion

The comparison made in Table 1 of an open web joist with a rolled joist section ISMB 450 shows a saving of 40 per cent by weight of steel. A shed of 16 metre span and 24 metre length consisting of four portals of open web joist construction and the CMERI design of box purlins yielded a saving of 57 per cent by weight of steel against a conventional shed to the same specification. The experimental shed put up at CMERI to this new design and with available sections which were heavier than the calculated ones still affected a saving of 43 per cent against the conventional shed.

In a recent survey made by the National Council of Applied Economics Research, it has been shown that the use of tubular trusses could save considerable steel. A comparative study (Table 3) has been made by CMERI of the newly developed design with that of the tubular trusses.

The NCAER study shows a saving of 24.8 per cent over a conventional roof truss of 44 ft span, if tubular truss is adopted. Using CMERI developed designs the saving on a similar truss would be of the order of 45 per cent. This shows that the newly developed designs could save 27 per cent more steel over the tubular truss for the particular span.

This fact brings out the prospect of applying the CMERI designs for trusses of small spans carrying light loads, wherein hitherto tubular trusses were being used with advantage. Taking note of higher market price for

Table 1—Computation of section parameters and weight comparison

Type of Joist	Weight per metre w (kg.)	Section area a (cm.^{2})	Depth of section h (mm.)	Width of flange b (mm.)	Thickness of flange tf (mm.)	Thickness of web t_w(mm.)	Moments of inertia		Radii of gyration		Moduli of section	
							I_{xx} (cm.^{4})	I_{yy}(cm.^{4})	r_{xx}(cm.)	r_{yy}(cm.)	Z_{xx}(cm.^{3})	Z_{yy}(cm.)
Open web	43.5	48.84	645	188	8	28	42990	830	20.0	4.12	1433	88
ISMB 450	72.4	92.27	450	150	17.4	9.4	30390.8	834	18.15	3.01	1350.7	111

Table 2—Comparative weight estimates of shed

(weight in kg.)

Type of shed	Weight of roof truss	Weight of two columns	Weight of portal	Weight of purlins	Weight of wind tie	Total weight of 24 metre length shed
Portal shed	826.5	748	1534.5	3800	873	10971
Conventional shed	1117	1170	2287	8528	1659	25524

Table 3—Weight estimates of covered area

Type of truss	CMERI design	Tubular	Conventional
Span (ft)	44	44	44
Weight (lb./ft^2)	1.5	2.12	2.82
Percentage saving by weight over conventional truss	45	24.8	
Percentage saving by weight over tubular truss	27		

tubes as compared to angles and bars, the overall economy of replacing tubular trusses by CMERI design of trusses could be very considerable.

In the experimental shed put up at CMERI only four sections — two angle and two rod sections — are used. This effects further saving in inventories and procurement. The ready availability of these sections in the market and the design which lends itself especially to mass production would cut down the time for construction work and thus speed up the industrialization programme.

A further important point is the ease of erection of these light-weight portals at site. The absence of machined gussets and bolted connections makes it possible to place the purlins in the proper position, and weld them at site obviating all allignment problems. The CMERI structure was constructed and erected at site by M/s Apeejay Structurals in a period of six weeks. The cost of construction and erection of these structures are no more than cost of construction and erection of conventional structures as borne from experience in putting up experimental shed at CMERI and a structure in the Institute's MERDO Centre at Poona. Thus the saving in using these structures would not only be that of the steel saved, but also proportionality of the total cost of present day structures.

Conclusion

The advantages of the economical design developed by CMERI over the conventional structures can be summed up as follows :

1. Saving in steel of over 30 per cent in every case.
2. Use only angles and bars which are readily available in the market.
3. Time lag in construction is reduced because of easy availability of sections used.
4. Design lends itself to mass fabrication and quick erection, which could also advance erection schedules of many industrial projects.
5. Saving in foundations due to light-weight of the structure.
6. Use of plates, which are rather difficult to get, is reduced to the barest minimum.
7. High tensile or special steels not available in India are completely avoided.

It has also been found that the CMERI design of economical roof trusses is even lighter than the much publicized tubular trusses.

The impact of the new light-weight design developed by CMERI can well mean a minimum saving of Rs 100 crores during the Fourth Plan period. This could in fact be a saving in foreign exchange since Rs 500 crores worth of steel is expected to be imported during the Fourth Plan period.

If research could be extended in redesigning medium heavy and heavy structures to apply the design concept developed at CMERI with built up sections, the above saving could very well be doubled.

This emphasizes the importance of structural research in relieving the present foreign exchange and economic crises in the country. This calls for increased research facilities in the form of equipment involving a few lakhs of rupees foreign exchange. The investment of a few lakhs of rupees in foreign exchange, even in the present crisis, on a research project with a potential for saving a few crores of rupees foreign exchange, is fully justified and called for.

Nomenclature

A_F=area of the semi-flange, cm.^{2}
A_w=area of the web, cm.^{2}
b, h=widths of angle legs, mm.
k=ratio h/b
t=thickness of the angle section, mm.
α=centroidal distance of flange elements, cm.
D=rod diameter, mm.
I=moment of inertia, cm.^{4}
Z=section modulus, cm.^{3}
L=length of the beam, m.
P=Applied load, kg.
M=bending moment, kg./m.
S=shear force, kg.
σ_b=bending stress, kg./cm.^{2}
σ_t=diagonal tensile stress, kg./cm.^{2}
$(\sigma_b)_w$=allowable bending stress, kg./cm.^{2}
$(\sigma_t)_w$=allowable diagonal tensile stress, kg./cm.^{2}
σ_y=Yield stress, kg./cm.^{2}
λ=Lagrange multiplier
T=diagonal tensile load

The following frame constants are used in deriving expressions for bending moments and shear forces in the portal analysis:

$$\eta = I_1/I_2,\ q/h$$

$$q = \sqrt{f^2 + \frac{L^2}{4}}$$

$$\psi = f/h$$

$$A = 4\left(3 + 3\psi^2 + \psi^2 + \frac{1}{\eta}\right)$$

$$B = 2(3 + 2\psi)$$

$$K = \tfrac{5}{4}(2 + \psi)$$

Utilization of Indigenous Amphibole Variety of Asbestos for Production of Asbestos Cement Sheets and Pipes

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One of the principal uses of asbestos is in the manufacture of asbestos cement products, the demand of which is increasing progressively in India in keeping with the accelerated pace of industrialization and plans for housing. This growing demand of asbestos cement products is being met at present by manufacturers by import of chrysotile variety of asbestos involving foreign exchange to an extent of Rs 4 crores. It is estimated that the requirement during the Fourth Plan would be about 20 crores. Excepting Cudappa, all other sources of asbestos in India yield only amphibole variety which has not yet found use in the manufacture of asbestos cement products. The reserves and production of Indian asbestos are given in Tables 1 and 2.

Table 1—Reserve of asbestos

State	Quantity (tons)	Variety	Remarks
Andhra	250,000	Chrysotile	A belt of about 9½ miles long (up to a depth of 660 ft)
Bihar	350,000	Tremolite	Mining is done at several places
Madras	Not estimated	Tremolite	
Orissa	Not estimated	Amphibole	Some mining is done
Mysore	25,000	Tremolite	Up to a depth of 100 ft only in Hassan District; deposits are deleted in other districts too
Madhya Pradesh	Not estimated	Amphibole	Mining being done at number of places
Rajasthan	Not estimated	Tremolite	Mining carried out at various places
Bombay	Not estimated	Tremolite	Some mining is done
Uttar Pradesh	Not estimated	Chrysotile	Average length of fibre ranges from 4 to 6 in.
Himachal Pradesh	Not estimated	Tremolite	

Table 2—Production of asbestos in different States of India
(in tons)

State	1948	1951	1952	1953	1954	1955
Andhra	—	136	241	258	121	327
Bihar	15	239	227	125	78	115
Bombay	—	—	—	—	10	20
Madhya Pradesh	39	61	—	50	25	70
Mysore	28	82	215	53	43	150
Rajasthan	—	—	182	252	112	675
TOTAL	82	518	865	738	389	1357

There was in practice no process for the exploitation of amphibole fibres for the production of asbestos cement products. The availability of these fibres is in abundance in the country and the urgency to save foreign exchange by all means prompted the CFRI to develop a process by which the imported chrysotile variety could be successfully replaced by the indigenous amphibole variety for manufacture of asbestos cement products. This would also benefit the industry to a large extent by eliminating the need for dependence on imports. These investigations which are discussed in the following lines have conclusively shown that the amphibole fibres could be used on a commercial scale for the production of high class asbestos products having properties even better than the standard market products.

Asbestos fibres generally occur in bundles. Therefore, the primary requisite in the treatment of asbestos fibres for the manufacture of asbestos cement products is the opening up of the fibres. The conventional practice for opening up of the fibres, as followed by the industries, is by crushing and disintegration, but this mechanical treatment reduces these fibres to a powder like mass. These powder like mass do not produce asbestos cement products of standard specifications. Therefore, the successful utilization of amphibole variety of asbestos depends entirely on the method of processing the fibres without shortening its length. This has been achieved in CFRI by the use of surface active reagent which opens up the fibres without appreciably reducing the fibre length (small in comparision with good quality chrysotile variety). The degree of opening has been measured by a test known in Industry as 'Buoyancy Test'. It is known from experience that the buoyancy value of the fibres must be more than 40 per cent in order to produce good sheets out of them. Results of this test are given in Table 3. It would be observed that the buoyancy value of the amphibole fibres has increased considerably as the result of the treatment with the surface active reagent.

The utilization of short-fibre asbestos as we have in this country will, however, be dependent upon the method of manufacture. The lamination method as is usually practised for the long-fibre asbestos is not suitable for the short fibres. Therefore, we adopted the pressure method for the purpose as followed in other foreign countries.

A.C. sheets have been made with the processed material on the laboratory scale. The process, discussed below, was restricted to the

Table 3—Results of buoyancy tests on different asbestos fibres

Details of sample	Buoyancy in distilled water in % of the raw fibre	Buoyancy in water % of the surface active reagent treated fibre
1. Rhodesian Chrysotile fibre* (Mechanically opened up)	40.2	—
2. Canadian Chrysotile	29.8	43.5
3. Cudappa Chrysotile	25.0	42.0
4. Seraikela Amphibole	35.0	81.0

*Obtained from M/s Rhotas Industries Ltd, Dalmianagar

production of 10 in. × 10 in. × ¼ in. A.C. flat sheets in batch operations using a hydraulic press and in suitable moulds.

Method of preparation

A known weight of asbestos fibre was added to a solution containing 0.1 per cent of the commercial surface active reagent and was kept under agitation for 6 hr by blowing air through it. Then the mixture was filtered in a Buchner funnel and washed free from the reagent. The treated fibres were taken in water and required amount of portland cement (asbestos : cement : : 1 : 5 or asbestos : cement : : 1 : 8) was added to it. Sufficient water was added at this stage to make a thin slurry and the slurry was kept under agitation for 15 min. by blowing air through it. Then the whole mass was filtered through a Buchner funnel under suction to a water/cement ratio of about 0.50. The paste of asbestos and cement, thus produced, was then subjected to a hydraulic pressure of 800 lb./sq. in. to squeeze out a part of the water, ensuring a water/cement ratio of 0.35 to 0.40 to the final product. The sheets thus cast, were weathered for a day on a supporting base plate and then the sheets were immersed under water at least for 28 days for curing before testing. In America and other countries, the modern trend to produce A.C. sheets is by a combination of lamination and pressure methods were a blend of long and short asbestos fibres is used. With a view to exploring the possibility of adopting the technique of blending long and short fibres, we have tried to produce A.C. sheet from different mixtures of amphibole and chrysotile fibres applying the pressure method alone. The transverse strength of the asbestos cement flat sheets of different compositions prepared in this laboratory were tested in the factory of M/s Rohtas Industries Ltd, Dalmianagar. The results are given in Table 4.

Plant scale experiment for production of asbestos cement pipes

Some plant scale experiments were also carried out for the manufacture of asbestos cement pipes using amphibole fibre at one of the pipe making works of M/s Asbestos Cement Ltd, Bombay.

The amphibole variety of asbestos fibres which were used in these experiments were obtained from the Dholadihi Mines in Bihar through

Table 4—Transverse strength test results of asbestos cement flat sheets prepared at CFRI

(Pressure, 800 lb./sq. in.; Asbestos/cement ratio, 1 : 8; curing time under water, 28 days; thickness of sheets, 6.25 mm.)

Sl No.	Dholadih amphibole	Rhodesian chrysotile	Av. transverse strength in lb. tested over a span of 9 in. (using 10 × 10 in. specimen)
1.	100	—	100
2.	90	10	102
3.	80	20	100
4.	75	25	108
5.	70	30	110
6.	65	35	110
7.	60	40	112
8.	55	45	115
9.	50	50	105
10.	—	100	117

the District Mining Officer, Singhbhum, Bihar. The sample was received in a very crude form contaminated with stones which were separated bv hand picking.

A known weight of amphibole fibre was added to a solution containing 0.2 per cent of the commercial surface active reagent and was kept under mechanical agitation for about an hour in a small mixer. The required amount of chrysotile fibre was added at an intermediate stage of agitation and the agitation was continued for an hour. Then the required amount of portland cement (asbestos : cement : : 1 : 10 or asbestos : cement : : 1 : 8) was added to it along with extra water, if required, to obtain the required consistency and kept under agitation for another 10–15 min. The pipes were formed from the slurry by a 'Forming Roller' on a removable iron mandrel maintained at a certain vacuum, the product being rolled on to the mandrel. As soon as the desired thickness of pipe was obtained, the mandrel was removed from the machine and another was put in its place. There was provision for calendering the pipes on the mandrel prior to removal. Two sets of building pipes of each composition having diameter 2 – 3½ in. were made, one set calendered and the other set uncalendered. The pressure applied to the pipes was thus obtained from the Calender Roller. Though a pressure of 800 lb./sq. in. is generally applied during calendering in the normal process of manufacture using chrysotile fibre, a pressure of 300–400 lb./sq. in. was found sufficient for calendering the blended fibres and the product was found to satisfy the B.S.S. The iron mandrel was then replaced by a wooden mandrel and the product was kept aside for initial setting for 2–3 hr. Pipes, thus made, were then removed from the wooden mandrel, and weathered for a day on supporting racks, then kept immersed under water for 7 days and finally put in the open atmosphere for 21 days for curing before testing. The asbestos sheets could not be manufactured in their works as no facilities could be provided by them for making sheets.

Results and discussion

Asbestos cement sheets. It will be seen from Table 4 that it may be possible to manufacture standard A.C. flat sheets from blend of 80 per cent amphibole and 20 per cent chrysotile or 90 per cent amphibole and 10 per cent chrysotile or 100 per cent amphibole fibre (asbestos : cement : : 1 : 5 to 1 : 8). The results indicate that average transverse strength values are comparable with the B.S.S. for flat A.C. sheets.

Samples of amphibole variety of asbestos fibre, obtained from Seraikela, Bankasahi (Bihar), Jalainala (M.P.), were also successfully used for preparing flat sheets with satisfactory transverse strength.

Study of the test results leads us to conclude that if the sheets from amphibole fibres alone or from the blended fibres (if an initial orientation of the long fibres is imparted by the lamination method) are hydraulically pressed to about 1000 lb./sq. in. or more in order to increase the density, A.C. products of strength exceeding than that prescribed by the B.S.S. may be obtained.

Corrugated sheets and other such asbestos products which require a higher transverse strength, may be manufactured from amphibole fibres blended with a small quantity of chrysotile fibre by applying hydraulic pressure of about 1000 lb./sq. in.

Asbestos cement pipes. The ease of production of pipes in the existing machineries as well as the most encouraging bursting pressure

Table 5—Bursting pressure results of asbestos cement pipes made at M/s Asbestos Cement Co. Ltd following CFRI method

(Maximum pressure applied : 300-400 lb./sq. in.)

Sl No.	Pipe marked	Size of the pipe (l × dia.)	Composition		Asbestos/ Cement ratio	Bursting pressur e (lb./sq.in.)		Standard bursting pressure (lb./sq. in. B.S.S.)
			Amphibole %	Chrysotile %		Uncalendered	Calendered	
1.	WRI/196/1	6′ × 3½″	100	—	1:10	40		215
2.	WRI/196/1C	6′ × 3½″	100	—	1 : 10		(1) 150 (2) 110 (3) 90	215
3.	WRI/196/2	10′ × 2″	80	20	1 : 10	(1) 190 (2) 200 (3) 250		300
4.	WRI/196/2C	10′ × 2″	80	20	1 : 10		(1) 310 (3) 315 (3) 250	300
5.	WRI/196/3	10′ × 2″	50	50	1 : 10	(1) 400 (2) 275 (3) 340		300
6.	WRI/196/3C	10′ × 2″	50	50	1 : 10		(1) 370 (2) 360 (3) 340	300
7.	WRI/197/3	10′ × 2″	50	50	1 : 8	(1) 100 (2) 90 (3) 140		300
8.	WRI/197/3C	10′ × 2″	50	50	1 : 8		(1) 260 (2) 290 (3) 310	300

Table 6—Cost estimates of asbestos cement sheets

(Basis : Monthly production, 1200 tons)

Sample	Fibre/Cement ratio	Total cost of fibre* (Rs)	Cost of portland cement (Rs)	Total cost of production per ton** (Rs)	Total monthly cost of production (Rs)
100 % Chrysotile, 0.15 ton	1 : 5.7	195.00	90.95†	345.95	415140
100 % Chrysotile, 0.11 ton	1 : 8	143.00	95.23‡	298.23	357876
50 % Chrysotile, 0.075 ton +50 % Amphibole, 0.075 ton	1 : 5.7	135.00	90.95†	285.95	343140
50 % Chrysotile, 0.055 ton +50 % Amphibole, 0.055 ton	1 : 8	99.00	95.23‡	254.23	305026
20 % Chrysotile, 0.03 ton +80 % Amphibole, 0.12 ton	1 : 5.7	99.00	90.95†	249.95	299940
20 % Chrysotile, 0.022 ton +80 % Amphibole, 0.088 ton	1 : 8	72.60	95.23‡	227.83	273396
100 % Amphibole, 0.15 ton	1 : 5.7	75.00	90.95†	225.95	271140
100 % Amphibole, 0.11 ton	1 : 8	55.00	95.23‡	210.23	252276

*Chrysotile fibre at Rs 1300/ton, amphibole fibre at Rs 500/ton.

**Includes manufacturing cost of Rs 60.

†Cement 0.85 ton at Rs 107/ton.

‡Cement 0.89 ton at Rs 107/ton.

(Table 5) of pipes obtained from the blended fibres 50 per cent amphibole fibre plus 50 per cent chrysotile fibre (asbestos ; cement=1 : 10) suggests considerable potentialities for immediate commercial exploitation of the short-fibre variety. The results also indicate the possibilities of using the blend of 80 per cent amphibole and 20 per cent chrysotile fibre (asbestos : cement=1 : 10) for the production of A.C. pipes in the existing machineries with controlled calendering. It is true that amphibole fibre is deficient in some of the properties than the chrysotile fibre. But our objective is to compensate this deficiency in the asbestos cement products by the special technique adopted, i.e. by opening up of the amphibole fibre using a surface active reagent and forming the asbestos cement products at a sufficiently high pressure to get a more dense product. In the CFRI the pipes were manufactured at a low pressure (300–400 lb./sq. in.) with the existing machineries resulting in somewhat low results for bursting pressure for pipes from 100 per cent amphibole fibre. Greater attention for the development of suitable machineries for applying pressures up to 1000 lb./sq. in. is needed.

Table 6 gives the comparative cost of production of asbestos cement flat sheets made entirely from chrysotile or amphibole variety of abestos or from blends of the two. It is seen that indigenous variety of amphibole asbestos alone or their blends with small amount of chrysotile fibres will appreciably lower the cost of production of flat sheets.

Self-sufficiency in Cement During Fourth Five-Year Plan

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During the Fourth Five-Year Plan period, the shortage of cement required for civil engineering construction is estimated to be of the order of 40 million tonnes, for which the capital investment of Rs 160 crores will be necessary. Positive lines of action are suggested here for reducing the demand for cement as well as for increasing the production of cement, so that the financial outlay can be reduced by at least Rs 100 crores.

Introduction

The Planning Commission has computed that the annual requirement of cement in 1965-66 will be 14 million tonnes and this would rise to 26 million tonnes per year in 1970-71. On the other hand, at the end of the Third Five-Year Plan, the production of cement is now just about 10 million tonnes per year. If we are to reach the target of additional annual production of cement of 16 million tonnes in the next five years, the capital investment will be of the order of Rs 200 crores. At the beginning of the Third Five-Year Plan, about 30 per cent of cement machinery had to be imported and it was expected that this figure would go down to 10 per cent at the end of the plan period. If it is assumed that we have reached the expected level of machinery fabrication, the foreign exchange component of the Rs 200 crores investment will be about Rs 20 crores. At a time when financial resources are not available for projects more important than cement, it would not be possible to put the resources position to greater strain by allocating the required funds for the proposed expansion of the cement industry. The paper, therefore, proposes to discuss various alternatives to meet this crisis of cement shortage.

How to adjust the demand and supply positions of cement

The total requirement of cement for the Fourth Five-Year Plan period is expected to be 100 million tonnes and the total production at the current rate will be only 50 million tonnes. It is estimated that about 80 per cent of the cement requirements are consumed in the civil construction items. Hence if we assume that the requirement of cement for civil construction will be 80 million tonnes and the availability will be 40 million tonnes, the deficit is of the order of 40 million tonnes. To fill up the wide gap between the demand and the supply positions of cement, several remedies have been suggested from time to time, which can be classified as follows :

Reduction in demand for cement :

(i) Application of modern methods of structural design

(ii) Adoption of new construction techniques like prestressing, prefabrication, shell roofs, folded plates, composite construction, light-weight structures, etc.

(iii) Increased use of laboratories for concrete mix design and quality control during construction

(iv) Prevention of wastage of cement due to packing and in storage

(v) Use of substitute material like lime

Increase in production of cement :

(i) Increase in production of conventional cement

(ii) Addition of pozzolanic materials like fly ash, reactive surkhi, pulverized lime, calcined shale etc. up to 20 per cent of cement

(iii) Manufacture of blast furnace slag cement

Reduction in demand for cement

The requirement of 80 million tonnes of cement for civil construction is based on the conventional methods of structural design, the out-dated systems of construction and the wasteful practices of utilization of cement. The engineers as a community have to take up the challenge of the crisis of cement shortage by adopting modern methods of structural design and construction, and utilization of cement.

Modern methods of structural design. Design plays a significant part in the efficient utilization of structural materials. The more advanced a design, the more economical is the use of material. Improvement in the design can be achieved by arranging the construction materials to better advantage. For example, prestressed concrete design is an improvement on reinforced concrete because of the resultant economy in the use of steel and concrete to carry the same loads. There are several other advanced methods of design such as load factor method. Without much elaboration on this point, it is sufficient to point out that adoption of advanced design methods can effect considerable saving in the use of critical construction material like cement. It might be necessary to strengthen the design units of various engineering organizations in the country for this purpose.

Adoption of new construction techniques. In the case of heavy concentration of repetitive type of construction work, pre-fabrication of components leads to substantial saving of cement. Another mode of effecting reduction in consumption of cement is adoption of composite type of construction, where steel and concrete are most efficiently utilized. Similarly, slender shell roofs used for spanning large areas result in considerable saving of cement and steel and in reducing load on foundations. Utilization of light-weight construction materials also reduces load on the foundations. The economic advantages of these new construction techniques are familiar to the design and construction engineers, who must now overcome their conservatism and inertia in order to adopt them in use.

Utilization of laboratory facilities. The design of proper concrete mix design in a laboratory for the available materials like stone, sand and cement should be considered most essential at least for construction sites where more than 10 tonnes of cement is likely to be used. Similarly, for large construction works, quality control of concrete construction must be treated as obligatory. Since the government departments consume more

than 50 per cent of cement production, rigid rules for scientific use of cement should not be too difficult to enforce. Saving in consumption of cement is generally many times more than expenditure on computation of concrete mix design and exercise of quality control of construction.

It is roughly estimated that even with only 50 per cent implementation of the above proposals, a reduction in the demand for cement of at least 10 per cent would seem to be reasonable. It is true that this expected partial implementation would involve extra expenditure by way of strengthening of design units, setting up of control laboratories, and adjusting to new construction techniques. But we have got to make a beginning on these lines rather sooner than later. It is more justifiable to spend money on these items than on the production of more cement.

Prevention of wastage of cement. The present system of packing cement in gunny bags is wasteful in two ways, viz. (i) there is always some loss of cement through the gunny bags in transit, and (ii) due to aeration especially in humid climates, the effectiveness of cement is lost gradually in storage. It has been observed experimentally that within two years of storage the amount of cement retained on 90 micron IS sieve increased to about 30 per cent from the specified value of 10 per cent.

If we, therefore, switch over to packing of cement in suitable weather-proof bags, the savings in cement utilization can be of the order of 20 per cent. We are spending about Rs 20 per tonne for packing of cement and we are utilizing jute which has a considerable export value. It should not be too difficult and too expensive for our research organizations and cement industry to develop an alternate efficient material for packing cement.

Secondly, the engineers should take adequate care in storing cement required for construction, so that it does not get spoilt due to poor damp storage conditions.

With proper packing and storage conditions, an estimated saving of 5 per cent in consumption of cement is possible.

Use of substitute material like lime. Before the advent of cement, lime was the most common hydraulic binding agent used in the construction industry. The engineers now are reluctant to use lime as extensively as before. The reason is that cement is a standard product governed by rigid specifications which can be properly exercised in large units of the industry. On the other hand, lime is produced in a primitive fashion in a number of small units, where the quality of the product is not assured. But if good standard quality of lime is made available by modern large-scale lime-kilns, the engineers should not feel shy to use it as much as possible. In mortars for wall-plastering, lime can replace cement to a great extent. In the construction of dams, lime mortar can be most advantageously utilized. Lime can be extensively used in the foundation of structures, the canal linings etc.

According to the estimates of the Planning Commission, the consumption of lime in the construction industry is expected to rise from 1.2 million tonnes per year to 2.0 million tonnes per year in the Fourth Five-Year Plan period. If the engineers utilize as a minimum estimate another 5.0 million tonnes of lime in place of cement, the requirement figures for lime can be adjusted to 2.0 million tonnes per year at the beginning of the plan rising to 4.0 million tonnes per year towards the end. In any case, if the

cement supply is not readily available, the engineers will be forced to utilize lime wherever possible. We should take steps to see that at least sufficient quantity of lime is available to the consumers under such eventuality.

Economics of proposals for reduction in demand for cement. Taking into account all the above proposals, it is calculated as per details given below that the requirement of cement for construction purposes can be brought down to 63 million tonnes from 80 million tonnes for the plan period 1966 – 71.

SAVINGS :

(i)	Adoption of modern methods of structural design, new techniques of construction and scientific utilization of cement—saving of 10 per cent.	8 million tonnes
(ii)	Prevention of wastage of cement by using weather-proof bags for packing—estimated saving of 5 per cent.	4 million tonnes
(iii)	Utilization of lime to replace cement.	5 million tonnes
	TOTAL	17 million tonnes

Here the extra expenditure involved in the implementation of item (i), though justifiable and profitable in the long run, is too difficult to estimate, but we can afford to spend as much as Rs 20 crores on this account. Item (ii) should not account for any extra expenses, while item (iii), i.e. production of 5 million tonnes of lime would involve a capital investment of about Rs 3 crores.

Increase in production of cement

On a comparative basis, it can be assumed that the capital investments for setting up a million tonne per annum production plant for cement, lime and portland blast furnace slag cement are Rs 20 crores, Rs 6 crores and Rs 12 crores respectively. Keeping this in view, proposals for increasing production of cement are discussed below.

Increase in production of conventional cement. With the recent increase of Rs 13 per tonne allowed to the cement industry, it is expected that about Rs 3 to 4 crores per annum will be reinvested in the expansion of the industry resulting in the increase of 2 million tonnes of cement in the Fourth Five-Year Plan period.

Addition of pozzolanic materials to cement. It has been established that an addition of minimum of 20 per cent of pozzolanic materials like pulverized lime, reactive surkhi, fly ash etc. to cement does not affect its strength properties. We cannot expect individual consumer to add these pozzolanic materials at every construction site. The cement industry should, therefore, take a lead in manufacturing such admixed cements at the source. It is, therefore, suggested that at least 50 per cent of the production of the cement, i.e. 20 million tonnes should be mixed with the most economical admixture available at the cement factory. This factor alone will amount to 4 million tonnes of the required production.

It is true that about 4 million tonnes of fly ash is available per year at the various thermal power stations in the country. But unfortunately the locations of thermal power stations and of cement production units are not

always situated in such a way that this fly ash can be transported economically to cement factories for admixing purposes. Like fly ash, reactive surkhi can be mixed with cement, wherever the economics permits it.

But the most obvious material for addition to cement appears to be pulverized lime. Generally cement factories are located in areas where limestone is most easily available. Under the circumstances, production of pulverized lime under controlled conditions to desired specifications is definitely possible and economical. If the cost of production of cement is assumed to be Rs 100 per tonne, lime can be certainly produced at Rs 30 to Rs 40 per tonne. The production of lime is a considerably simpler process than that of cement and there will be no extra charges involved for the transportation of pulverized lime. The capital investment for setting up a modern type of lime-kiln should be about one-third of that for cement-plant for similar units of production. For a million tonne per annum production of lime and cement, capital investment is of the order of Rs 3 crores and Rs 10 crores respectively.

Assuming that we utilize only pulverized lime for addition to cement, the capital investment of only Rs 2.4 crores will be necessary for the production of 4 million tonnes of pulverized lime. No foreign exchange will be necessary for setting up these lime plants. The similar lime plants will also supply 5 million tonnes of lime suggested earlier for use as total replacement of cement. Therefore, the total investment for lime production will be of the order of Rs 6 crores.

Utilization of granulated blast furnace slag. The annual output of blast furnace slag from the steel industry is estimated to be 6 to 7 million tonnes. If slag processing plants are set up, about 3 million tonnes of granulated blast furnace slag can be processed every year. It is reported that slag from all the three public sector steel plants is suitable for the manufacture of portland blast furnace slag cement. The proportion of slag to cement in the mix would normally depend upon the chemical composition of the two ingredients, but as a rough estimate, a proportion of 30 per cent slag to 70 per cent portland cement is considered reasonable. If we propose to utilize one million tonnes out of the available granulated slag, the total production of portland blast furnace slag cement of about 3 million tonnes per year can be achieved. It means that in the plan period the total portland blast furnace slag cement production will be 15 million tonnes. There is already a licensed annual capacity of 1.2 million tonnes of portland blast furnace slag cement and this should be increased to 3 million tonnes per annum.

Economics of proposals for increase in production of cement. After taking into account these proposals, the production of cement can be stepped up to 61 million tonnes during the plan period as per details given below :

(i)	Production of cement according to the present installed capacity	40 million tonnes
(ii)	Extra capacity proposed to be installed during the plan period	2 million tonnes
(iii)	Extra production of cement due to 20 per cent addition of pozzolanic materials	4 million tonnes
(iv)	Production of blast furnace slag cement	15 million tonnes
	TOTAL	61 million tonnes

Comparative economics of the proposals

CASE 1 : Where all the deficit of 40 million tonnes of cement is to be made up in 5 years the capital investment of Rs 160 crores will be necessary.

CASE 2 : Where the demand of cement is reduced to 63 million tonnes and the production is stepped up to 61 million tonnes, the capital investment of only Rs 52 crores will be enough, the details of which are given below :

(i)	Provision for improved design and construction techniques	Rs 20 crores
(ii)	2 million tonnes of additional cement production	Rs 8 crores
(iii)	9 million tonnes of lime (out of this, 5 million tonnes of lime is required for total replacement of cement and 4 million tonnes for 20 per cent replacement of cement)	Rs 6 crores
(iv)	15 million tonnes of portland blast furnace slag cement	Rs 18 crores

Thus there can be a saving of more than Rs 100 crores in the total financial outlay.

Conclusion

It is to be pointed out that the proposals of substitution of cement by lime or by granulated slag can be finalized only after detailed considerations of cost of production, capital investment, availability of raw materials and machinery etc. are thoroughly studied. The present proposals apart from economizing on the capital investment for production of cement by more than Rs 100 crores have the following main features :

(i) Implementation of rational and advanced structural design methods. (ii) Adoption of material-saving construction techniques. (iii) Scientific utilization of cement. (iv) Development of proper packing material for cement. (v) Substantial use of lime instead of cement. (vi) Partial substitution of cement by pozzolanic materials like pulverized lime, fly ash, reactive surkhi etc. (vii) Utilization of granulated blast furnace slag, which constitutes a problem for disposal to the steel industry. (viii) More flexibility in production and utilization of hydraulic binders when more varieties like portland cement, lime, pozzolan-cement, portland blast furnace slag cement etc. are available to the consumer.

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Need for Urban Traffic and Transportation Planning

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Present urban traffic conditions

Since the attainment of independence, many industrial units have come up in and around big cities of the country. Such an industrial development and also other opportunities for employment have resulted in the concentration of population in these cities, the trend of which is increasing every year. This trend has resulted in the rapid increase in number of vehicles in these cities and consequently in corresponding increase in road accidents. For example in Delhi during 1958–64, motor vehicles increased by 181 per cent and the population by 32 per cent whereas the road accidents increased by 186 per cent indicating an average increase of 31 per cent per year. The population, motor vehicles and road accidents in Delhi during 1958–64 are given in Table 1.

Haphazard growth and inadequate road and street system of the cities further aggravate the increasing trend in accidents and congestion. It is therefore essential that the highway authorities give due consideration to the consequence of this trend. It is not adequate if they just carry out the widening of a few roads, or improvement of geometric features of a few intersections or some such spot improvements here and there. Such improvements offer only temporary relief at the spots. To ensure efficient and safe flow of traffic in the cities, it is necessary to visualize the problems comprehensively and work out improvements to meet the demand of the present as well as future traffic.

Traffic planning in advanced countries

Traffic and transportation plan is prepared for all towns and cities in advanced countries like USA and Germany. In Germany importance was given to this field next to housing in the construction of cities after the war.

Table 1—Population, motor vehicles and road accidents

Year	Population	No. of motor vehicles	No. of road accidents
1958	2342700	23725	2838
1959	2443600	27539	3700
1960	2546800	35232	4800
1961	2658612	41052	6045
1962	2798029	47898	7234
1963	2944756	57791	7199
1964	3099179	66742	8066

General plans on land use and traffic and transportation have been worked out for each city by the city building office, which has departments for planning the work as well as for the execution. Such an administrative set up facilitates the execution of the general plans without difficulty. Besides, the entire metropolitan area is under the jurisdiction of the city building office, which makes the planning easier.

To decongest the cities, employment and business opportunities are provided outside the area, which is under the economic influence of the city. In other words the city's population is controlled and regulated in order to ensure free movement of traffic. Such improvements also help in the improvement of the social and cultural life of the people.

Traffic planning in India

In our country, traffic and transportation planning has not been given due importance considering the rapid urban development. The Town Planning authorities have taken up the question of urban planning but they do not cover traffic and transportation planning. Such a plan will not be successful, unless planning for traffic circulation system is taken into consideration. Of late, the highway and traffic authorities in a few metropolitan cities have realized the importance of comprehensive traffic planning and have taken up such work. Traffic planning studies were carried out in Bombay by a foreign firm at a cost of about 20 lakhs. A part of this amount has to be paid in foreign currency. The follow-up studies of the above traffic planning and transportation studies, which are proposed to be conducted by foreign experts, will also cost considerably, involving a lot of foreign exchange. A similar work is being carried out in Calcutta by State Planning Organization with the help of foreign experts and also to a limited extent the Central Road Research Institute.

It is very essential to carry out such studies at least in important metropolitan cities in the immediate future. For such planning, if the help of foreign firms or foreign experts is sought as at present, it would involve considerable foreign exchange. To solve this difficulty, it is necessary to pool the trained personnel available in the country and undertake such planning work. This also provides the opportunity for development of traffic planning techniques to suit the mixed traffic and socio-economic conditions in the country.

Traffic Consultancy Cell

On the request of Mysore Government, the Central Road Research Institute, New Delhi, has taken up such planning work for Bangalore Metropolitan Area. Studies have been undertaken to assess traffic and transportation demands. The present demands will be projected to the design year 1938 and to meet this, facilities will be designed. This Institute carried out traffic investigations in Delhi and also for Calcutta Metropolitan Planning Organization. It is proposed to take up such work for Bhilai in the near future. Such planning work also provides for better utilization of research results. At present this Institute is carrying out such work in addition to research work on engineering, education and enforcement aspects of traffic problems, only when it can be fitted in.

As pointed out earlier, there is an immediate need to carry out such planning work in many metropolitan cities in the country. It would be difficult for this Institute to mix up such large demands with its research

work. Considering the above facts there is an urgent need to start a 'Traffic Consultancy Cell' in this Institute on a self-sustaining commercial basis, so as to forestall the tendency towards foreign consultancy, which is bound to grow if facilities are not provided within the country.

Conclusion

In view of the urgent demand for carrying out traffic and transportation planning work in big cities, a self-supporting Traffic Consultancy Cell on a commercial level should be started in the Central Road Research Institute.

Role of National Laboratories in Design Consultancy Services in Foundation Engineering

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The paper attempts to spotlight the increasing demand for consultancy services in the field of foundation engineering and our present insufficiency to meet the demand and finally suggests the line of action to remove the deficiency. Most of the experiences recounted are perhaps no less applicable to other individuals and organizations placed in a similar situation. The need for consultancy services in foundation engineering from the view point of the national requirements of the industry and the civil engineering profession, and the question of whether or how the concerned national laboratories should participate in consulting activity from the viewpoint of research are discussed.

Need for consultancy services

Design consultancy services in foundation engineering would normally include subsoil exploration, soil sampling and testing, foundation analysis, selection of the most appropriate type of foundation and sometimes the structural design of the foundation itself. There is considerable scope for economizing on the cost of structures through the application of the nascent science of foundations and soil mechanics to the solution of foundation problems. Especially in the construction of roads, buildings, grain silos, harbour and dock structures, the demand for consultancy services in the shape of subsurface exploration, sampling, testing, analysis and design recommendations is becoming increasingly apparent. The experiences of the CRRI point clearly to the fact that considering the increasing tempo of construction activity there exists an utter lack of adequate facilities in the country for conducting even the minimum of soil investigations before superstructures worth several lakhs of rupees are built. Many chief engineers of major projects are known to be hard put to it to find contractors who would agree to do the boring operations and collect undisturbed soil samples. Besides the work of boring, sampling and testing, the foundation analysis of different structures require the specialized experience of foundation engineers who have achieved success in practice. There is not any set organization available to which the client can look up to, for advice and assistance. In India, the civil engineering profession is mostly in the domain of the Government sector. There has been very little of consultant practice in the private enterprise. This is presumably responsible for the insufficiency of consulting services that confront the profession. What is more, the concerned national laboratories such as the CBRI and CRRI are constrained to limit the type and amount of the work that they can undertake without detriment to their normal work on research programmes.

The CRRI is painfully aware of many instances where foreign collaboration is being sought for consulting advice on foundation problems without even caring to determine whether qualified and competent engineers who can give such advice are available within the country. Of course, there are a few specific examples in the experience of the CRRI wherein due to the individual resourcefulness on the part of Chief Engineers, problems that would have in the normal course of things, been referred to foreign firms or experts, had been placed in the hands of the CRRI who undertook to advise, thereby considerably economizing on cost including foreign exchange. There are even specific cases where foreign contracting firms have sought the advice of the CRRI.

If only consultancy services can be made available in an organized fashion to the prospective clients both in the private and in the public sectors, the need for or the dependence on foreign expertise in this field can be largely eliminated.

From the reasoning set out, it appears that what is sorely needed is an organized design consultancy unit to which the various departments can address their vexing foundation engineering problems for solution. Such a unit should draw upon the resources of men with a high level of professional competence who will be in readiness to undertake to report on the different foundation projects that are referred to them. It cannot be forgotten that foundation engineering is still an art although scientific developments have greatly contributed to the practice of the art. Today there are only a few organizations within the country fully equipped with field and laboratory equipments and above all, with the needed type of personnel to take up challenging foundation engineering projects. We need men —and need them sorely—men who have devoted their years not merely to sampling and testing and interpretation of test results but also to the development of the faculty of observing the behaviour of the soil in the field, who have an eye on the limitations of test conditions of the soil samples, and who can evaluate the anticipated behaviour of the superstructure. It would therefore appear that the consultancy unit should start with a small nucleus of experienced personnel and grow with the growth in opportunities. Thus a close-knit and continually growing team of expert engineers can easily be nurtured so that the unit can gradually develop into a self-supporting institution.

The imperative need for making a concerted and organized effort for providing the nation with a design consultancy service unit exclusively in the field of foundation engineering is readily recognized if only one would pause and think of the colossal foundation problems that are to be tackled in the field of docks and harbours ; in the correction of landslides that confront the Border Roads Organization ; in the construction of multi-storeyed buildings ; in the building of roads and embankments on swamps and marsh, such as in the Rann of Kutch ; and in bridge construction. It is to be noted that even the Indian National Society of Soil Mechanics and Foundation Engineering has been voicing the need for the formation of such a consultative unit in the recent months.

Participation by national laboratories in consultancy activity

If the problem of consultancy services is looked at from the perspective of research interests, the case for national laboratories undertaking design consultancy assignments in foundation engineering becomes even stronger.

Many special opportunities and problems confront the national laboratory which finds itself often called upon to act in a consulting capacity. Considering the fact that soil mechanics had experienced its early growth in academic settings, it is quite understandable that teachers and research workers should engage themselves in the role of a consultant. However, the question of whether at all or along what lines the research engineer, professor or the organization should operate, is rather a debatable point. One of the many justifying and even compelling reasons as to why the research staff should associate themselves in the design of actual field projects is, that the accumulated experience cannot go profitless, without improving the breadth and vigour of research. Another is, that some aspects of the work will afford a valuable opportunity for the research staff to participate directly in the solution of current engineering problems. A third reason is that the work provides not merely stimuli but pabulum for research, besides giving an insight into the significance of research problems worthy of additional investigation. Finally, the experience furnishes the research engineer or the organization as the case may be, with raw material for professional paper and even textbooks, as is evidenced by the fact that the majority of modern textbooks are written by teacher-consultants rather than by members of contracting or engineering construction organizations. It therefore seems both necessary and desirable that the research staff should, if they could, participate in consulting activity on field projects.

Of course, it is obvious that in a tax-supported research institution or laboratory, one should meticulously avoid the uncompensated use of public funds for private gain. One foremost criterion in deciding whether or not a consulting assignment is appropriate on the part of a research organization even on full payment should probably be, that the assignment should call forth the special skills of the research organization, ensuring that the work is not routine or such as can be easily undertaken by a firm offering soil testing services.

Now and then, field assignments may have to be accepted, which do not fit in with this requirement. What is more, one cannot always tell in advance, if a project will be routine in nature, since the type of soil testing and the interpretation of test results largely depend upon the pattern in which the project develops or unfolds itself, on a day-to-day basis. For instance, a routine-looking investigation into the causes of settlement of a multi-storeyed building, led ultimately to the study of hydrodynamic consolidation characteristics of soil peculiar to the region concerned. Furthermore, the correlation between the results of load tests and the standard penetration values obtained during the course of the investigation pointed to a usable research result, viz. that in the case of loessial soils, whereas the bearing values at natural moisture content, on the basis of load tests, comes out to be fairly high, the penetration values will be glaringly low in comparison. In another project involving large embankment construction on soft ground, the attempts of the CRRI to account for the continual subsidence of an approach embankment resting on soft clay, occasioned a legitimate doubt concerning the creep strength of the clay. This led to a systematic and very useful research investigation on the creep strength phenomenon in different types of clays and the problem was successfully tackled on the basis of the results of such an investigation. These represent some typical examples which demonstrate—if demonstration be needed—that research grows with the growth of opportunities for practical application of research results to the solution of difficult problems.

Conclusion

In brief, the following are the points that emanate from the analysis :

1. There is an inexorable demand for design consultancy services in foundation engineering from the civil engineering profession in this country, both in the government and in the private sectors.

2. The need for dependence on foreign expertise can be largely eliminated if only consultancy services can be made available in an organized fashion. The CRRI is in a position to exemplify this point by the consulting works that it has already undertaken with respect to the Vizag Ore Handling Scheme, the design of the Cargo Jetties at the Kandla Port and the Reclamation Scheme at Mormugao, most of which are undertaken on behalf of the Ministry of Transport. Understandably, the pressure for consultancy work has been steadily increasing from the various Ministries including the Ministry of Food and Agriculture who are called upon to erect grain silos under problematic foundation conditions. The CRRI has been accepting such assignments on a selective basis but has perforce to deny the assistance asked for in many, many cases for no better reason than that its budgetary resources do not allow the laboratory to ramify its functions any further.

3. It is established that in the interests of research, a national laboratory should participate in consulting activity.

Suggested line of action

1. On the basis of considerations given above, it would appear that the CSIR should take upon itself the task of giving a fillip for the inception of a design consultancy unit functioning under its auspices. Since the unit can draw its financial sustenance from the consulting fees which are willingly paid to it by the clients, no great financial commitments are foreseen, other than those of providing for the basic equipments and staff.

2. It is suggested that a recommendation be made to the CSIR that the national laboratories concerned with civil engineering subjects, should be authorized to augment their existing consultancy services in foundation engineering by having in them a cell exclusively devoted for the purpose on a commercial basis (as distinct and separate from the extension work of the laboratory), and to train up soil engineers with the needed professional personality and level of technical competence. By merely augmenting existing facilities, the laboratory could be better fitted to play its legitimate role in assisting the industry and the engineering profession.

3. Prior to entering into international commitments, contracts and aid programmes relating to civil engineering projects, efforts should be made to limit the element of foreign assistance in the field of foundation engineering to the minimum by availing of the services of the proposed consultative unit.

Discussion on Indigenous Manufacture of Road Making Machinery

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The art and science of road making can be traced back to fairly old times. During the intervening period, both the road and the vehicle have been undergoing modifications to suit the needs of time. In contrast to the practices prevailing in some of the developed countries, road construction in India is largely carried out manually. Even though it is important at this stage that manual power be utilized to the maximum possible extent, equally important is also the appreciation that certain phases of road construction need to be mechanized in the interest of constructional quality, long term economy and speed of construction.

Our Twenty-Year Road Development Plan (1961–81) envisages a much faster rate of construction than that undertaken in the past. As seen from the Transport-Communications Monthly Review for June 1965, the tentative approximate requirement of road making machinery during the Fourth Five-Year Plan period is as given in the Appendix. Added to the needs of this Plan are those of the border roads and the various defence schemes. Many a time, construction on defence schemes involves work to be carried out at top speed in remote areas with unfavourable environment. With manual construction, the race against time becomes still more difficult. Again, in view of the needs of the growing traffic certain road facilities require to be provided with superior surfacings which cannot be constructed satisfactorily by manual methods. To achieve the desired type, rate and quality of construction as well as long term economy, it is necessary that we introduce mechanization in certain operations of highway construction with a phased programme for complete mechanization. Some of the operations requiring particular attention at this stage for mechanization are those related to in-place stabilization of soil, spreading of binder and grit for bituminous surface dressing work and laying of superior bituminous constructions and of cement concrete pavement.

Now and then, a few items of road construction machinery might be imported for foreign aid projects, certain defence projects or, rarely, for some other important projects. With the foreign exchange position becoming increasingly acute, the import of road construction machinery is practically ruled out for a large number of projects. It is not uncommon to find an organization forced to adopt manual methods, even though undesirable for certain phases, merely to meet the need for going ahead with the project under all conditions. In view of the above, it is high time that we turn to indigenous manufacture for almost all our requirements of road making machinery.

Broadly speaking, road schemes are sponsored and financed by the Government/public sector. Even in cases where the construction is got

carried out from a contracting agency, by and large all heavy machinery is invariably supplied by the Department. Therefore, there cannot be two opinions about the need for the initiation by the Government of schemes for the indigenous manufacture of road making machinery. Besides inducements and the requisite protection, the industry could be helped further by making available the approximate requirements of various types of machinery during the next 10–20 years.

Some concrete steps are indicated at this stage to provide the much needed initial push to the case of indigenous manufacture of road making machinery. It would appear necessary that a permanent committee consisting of representatives from the concerned organizations be set up to plan and organize the coordinated production of road making machinery within the country and to review the position from time to time. For the translation of the broad policies of the permanent committee into concrete proposals, the permanent committee may have to be assisted by a group of specialists. In consultation with the group of specialists, the permanent committee may study the different types of design in each category of machinery to be indigenously produced and may select one or two types which will be most suited to the conditions of manufacture and usage prevalent in the country. The group of specialists may prepare detailed working drawings and specifications for the manufacture. The Government may then organize the production through appropriate undertakings. To start with, some machine parts/materials may have to be imported. However, the quantum of these imports can be made to taper off through the coordinated efforts of various research and development organizations existing in the country. The Working Group for Scientific Research in their Draft Fourth Five-Year Plan recommended that the indigenous manufacture of road making machinery at an early date to be the responsibility of the Central Road Research Institute.

Recommendations

In the background of the above discussion, the following recommendations would appear in order :

1. It is suggested that the approximate requirements of different types of road making machinery for the next 10–15 years should be assessed immediately by a small committee of possible users.

2. A permanent committee consisting of representatives from the Ministry of Commerce and Industry, the Ministry of Transport and Communications (Roads Wing), the Indian Roads Congress, the Central Road Research Institute etc., should be set up to plan and arrange for the coordinated production of road making machinery within the country, and to review the position from time to time. The Central Mechanical Engineering Research Institute may also be very usefully associated in this.

The responsibility for importing pieces of selected machinery for manufacture within the country and producing working drawings for that purpose should be entrusted to the CRRI which may be assisted by the CMERI. The idea would be to manufacture prototypes within the country and to produce working drawings for being handed over to selected industrial concerns for manufacture on terms suitable to the requirements of the case.

The allocation of Rs 33 lakhs already made by the Roads Wing,

Ministry of Transport for the procurement of road making machinery could be advantageously made use of to serve this purpose as well.

The idea would be to rig up the various pieces of machinery as far as possible with available internal resources and with as small an element of imported parts as possible, say about 5 to 10 per cent. Research would be initiated within the country to gradually reduce the element of these imported components. This would also be arranged by CRRI with the help of the CMERI and any other assistance that might be available within the country.

3. The CRRI may be asked to prepare a detailed scheme for this purpose in consultation with the CMERI.

APPENDIX

Tentative (approximate) requirements of road making machinery during Fourth Five-Year Plan period

	Nos.
1. Road Rollers:	
(a) 8/10 ton Road Roller	5,000
(b) 4–6 & 6–8 Tandem Rollers	400
(c) Rubber-tyred Road Rollers 4–5 tons	200
(d) Crawler Road Roller	200
(e) Sheepsfoot Rollers	200
(f) Vibratory Rollers 3–5 tons	50
2. Dozers 150 H.P.	325
3. Motorized Scrapers 9–12 cu. ft capacity	125
4. Excavators / Grab Dredging Granes ¾ to 1 cu. yd capacity	150
5. Draglines ¾ cu. yd capacity	12
6. Dump Trucks 7.5–10 ton capacity	750
7. Loaders	75
8. Motor Graders 100 H.P.	430
9. Bitumen Boilers with Sprayers 300 gal. capacity	1,000
10. Storage Tanks 1,000 gal. capacity	100
11. Hot Mix Asphalt Plant 20–30 ton capacity	250
12. Bituminous Pavers 12–15 ft width	125
13. Bitumen Pressure Distributors 1,000 gal. capacity	300
14. Chip Spreaders or Gritters	300
15. Tippers 6 ton capacity	1,200
16. Asphalt Mixer: (a) 10/7 cu. ft; (b) 7/5 cu. ft	500
17. Air Compressors:	
(a) 210–250 dfm.	300
(b) 310 dfm.	200
18. Stone Crushers 10–12 ton capacity/hr	300
19. Granulators 5–6 ton capacity	100
20. (a) Pile Driving Plant 14 in. diam.	125
(b) Pile Driving Plant 5 ft diam.	25
21. Diamond Core Drilling Machines (2 in. diam. wires up to a depth of 100 ft)	100
22. Cement Grouting Machines	150
23. Concrete Mixers: (a) 10/7 cu. ft; (b) 7/5 cu. ft	700
(c) 1 cu. yd	50

		Nos.
24.	Vibrators :	
	(a) Needle	1,000
	(b) Screed	300
	(c) Form vibrator 10,000 r.p.m.	100
25.	Cement Batching Plant	44
26.	Pumps :	
	(a) 2″ × 2″ size (b) 6″ × 6″ size	500
27.	Workshop lorries	125
28.	Aluminium Launching Girders	12
29.	Cranes Mobile/Crawler :	
	(a) 5 ton	80
	(b) 10 ton	50
30.	Generators 25 kW.	100
31.	Diesel winches with $\frac{3}{4}$ to 1 cu. yd grab	150
32.	Wagon Drills	25
33.	Tractors (50 H.P.)	400
34.	Pick-up Vans	500
35.	Heavy Duty Hydraulic Jacks 100–200 ton capacity	50
36.	Power Rammers	300
37.	Rotavators	1,000*
38.	Prestressing Jacks for 5–7 mm. wires with maximum stroke of 300 mm.	30
39.	Helmets for Divers	400
40.	Joint Cutting Machines, max. cut 6 in.	50
41.	Bitumen Tank Railway Wagons, 20 ton capacity	
42.	Concrete Paver Finishers	6
43.	Mobile Batch Mixing Plant	12
44.	Core Cutting Machines 2–6 in. diam. for depth up to 18 in.	20

*Subsequently revised

Lime-Reactive Surkhi Mixture as Substitute for Cement in Masonry Mortars and Plasterings

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Need for alternate materials to cement

The present production rate of portland cement in the country is about 11 million tons a year, against the requirement of about 26 million tons a year during the Fourth Five-Year Plan. In order to bridge this huge gap, there is the immediate need of not only producing more cement in the country, but also evolving and marketing alternate materials that could act as cement substitutes on the basis of strength requirements of a particular construction. The latter is all the more significant because of the fact that besides the large initial outlay and significant amount of foreign exchange involved in the production of cement, the increase in the production of cement in the country cannot be stretched indefinitely in view of the limitations in the availability of the right grade of limestone. In this background there is an urgent necessity to restrict the incorporation of cement only to such constructions, where its use is a must, thereby avoiding the use of cement in those construction, where alternative materials could do the job equally efficiently.

Lime-puzzolana mixtures as cement substitute

Packaged, ready-to-use lime-puzzolana mixtures like lime-reactive surkhi mixture and lime-fly ash mixture, are suggested as alternative materials to cement in masonry constructions and foundation concretes, if only their production conforming to the high standards of industrial requirements and their correct usage are assured. A puzzolana is a siliceous or aluminous material, which by itself has no binding property, but which in the presence of lime and water could form products of reaction having cementitious properties. Common examples of puzzolanas are natural puzzolanas, like volcanic ash, diatomaceous earth, calcined clays and shales and industrial puzzolanas like fly ash. Among the natural puzzolanas, this country is rich in certain types of puzzolanic clays and shales, which could be suitably calcined at an optimum temperature and ground to minus IS 15 mesh size so as to yield a highly reactive clay puzzolana or 'reactive surkhi'. On the other hand industrial puzzolana like fly ash could be obtained from different thermal plants in the country. Lime-fly ash mixture refers to a suitably proportioned, intimately interground and blended mixture of dry, hydrated lime of high quality with processed fly ash from selected thermal stations capable of giving a material of the required reactivity (min. 600 p.s.i.), as specified in the appropriate IS Specifications (IS : 1905-1961). In the similar way, by lime-reactive surkhi mixture is meant a ready-to-use mixture of high quality fat-lime

and reactive surkhi with a minimum reactivity value of 1200 p.s.i. mixed in proper proportions. Both the mixtures could be brought into the market in properly packaged form for ready use in the construction works.

Strength of lime-puzzolana mortars

Mortars prepared from suitably proportioned lime-puzzolana mixtures have adequate strength, good plasticity and imperviousness. The compressive strengths of some lime-reactive surkhi mortars as obtained in actual construction works are given in Table 1. Table 2 gives the draft IS Specifications for the mix proportions of a few masonry mortars with lime-puzzolana and cement-sand mixtures. Those specifications pertaining to the lime-puzzolana mortars are based on the minimum IS requirement of a lime-reactivity of 600 p.s.i. for a puzzolana. Since this is the order of reactivity possessed by most of the fly ashes (L.R.=600–800 p.s.i.) available at present, it would be fair to assume that the given proportions would hold good for lime-fly ash mixtures. Table 2 also inculdes the CRRI findings on the mix proportions of lime-reactive surkhi-sand mortars of strengths equivalent to those specified in the IS Specifications.

Selection of lime-puzzolana mixture

It will be seen that because of its far higher lime-reactivity, lime-reaetive surkhi allows the use of much leaner mixes compared to lime-fly ash mixes

Table 1—Compressive strength of masonry mortars

(from field study)

Mortar mix proportions by wt			Compressive strength, p.s.i. at	
Lime	Reactive surkhi	Sand	7 days	28 days
1	1	8	159	300
1	1	10	140	304
1	2	8	474	755
1	2	12	240	459
1	3	12	278	533
1	3	15	211	478
Cement	Sand			
1	6		196	341

Table 2—Specified compressive strength of masonry mortars

(Draft IS Specifications of lime-puzzolana and cement-sand mortars and mix proportions of lime-reactive-surkhi sand mortars of corresponding strengths as per CRRI findings)

Mortar mix proportions by volume						Compressive strength (kg./cm.^{2} at 28 days)
Draft IS Specification			CRRI findings			
Lime	Puzzolana	Sand	Lime	Reactive surkhi	Sand	
1	1	2	1	2.5	8.75	7–15
1	2	0	1	2.5	7.5	15–20
1	3	0	1	2.5	6.25	20–30
Cement	Sand					
1	6		1	1.67	4.5	30–50
1	3		1	1.67	3.0	50 and above
			(For mortar of compressive strength up to 60 kg./sq. cm.)			

Table 3—Economy in using lime-reactive surkhi mortar or plaster

Type of mortar or plaster	Proportion of lime-reactive surkhi : sand (by vol.) (a)	Proportion of cement : sand (by vol.) (b)	Comparative economy in using (a) in place of (b)
Grade 30 mortar (28 days, compressive strength being 30 kg./sq. cm. and below)	1 : 1.8	1 : 6	26.5%
Grade 30-50 mortar	1 : 1.4	1 : 6	18.9%
Plaster	1 : 2.2	1 : 6	32.8%

to attain a particular level of strength. This fact as well as other factors like the availability of a particular puzzolana, cost of transport, overall requirements of such binders and the structural requirements of the masonry mortar in a work are some of the important considerations in the economical selection of the one or the other type of lime-puzzolana mortars for a particular work. The economy achieved through the use of lime-reactive surkhi mortars as compared to the use of cement mortar is given in Table 3.

Total requirement of binder for masonry mortar and plaster

Total requirement of cement in masonry work and corresponding lime-puzzolana mixture requirement. When the total production of cement in India was about 10 million tons in 1961–62, about 3.5 million tons were estimated to have been used up in building works alone. About 60 per cent of the cement used in small buildings and about 40 per cent of the quantity used in larger buildings are said to go for making mortars in such constructions. Taking an average figure of 50 per cent it may be estimated that about 1.75 million tons of cement were consumed in making building mortars during 1961–62. Taking into account the requirements of cement in the Fourth Plan at 26 million tons a year and a proportionate increase in the quantity of cement needed for building mortars, the Fourth Plan requirements for cement in making building mortars alone could be approximated at about 4.5 million tons per year. Assuming for calculation a proportion of 1 : 6 (by wt) for cement-sand mortar, for total substitution the requirement of lime-puzzolana mixtures, which will have a rough proportion with sand in the order of 1 :1 or 1 :3 (by wt), will run into roughly $4.5 \times 7/3$ (=about 10.5) million tons a year.

Estimated requirement of lime-puzzolana mixture and lime-reactive surkhi mixture in particular. It is certain that all prorportions of cement-sand mortar cannot be replaced by lime-puzzolana mortar in view of the lower strength achievement of the latter. Also other binders like semi-hydraulic and hydraulic limes, lime mixed with brick powder (Bazar surkhi), etc. would continue to be used to serve the same purpose. For assessment of requirement, therefore, a modest figure of 6.0 million tons a year of lime-puzzolana mixture could be taken as the target for achievement by the end of the Fourth Five-Year Plan. For this quantity of mixture about 4 million tons of puzzolana and about 2 million tons of lime will be required annually. In catering for this need, so far as the

availability of fly ash is concerned, not more than 1 to 2 million tons a year out of the total anticipated production 3–4 million tons a year of fly ash would be available towards the end of the Fourth Plan for the production of lime-puzzolana mixture. This is because a variety of uses for this material, such as the production of sintered light-weight aggregates and cellular concrete, manufacture of puzzolana cement, soil stabilization work, etc. have been suggested by different agencies and some of these proposals are either in advanced stage of implementation or under very active consideration of the authorities. Taking this alone into account, the total requirement of puzzolana will fall short by about 2–3 million tons a year. As already mentioned, this gap can be effectively bridged by the other source of puzzolana, i.e. reactive surkhi.

Availability of puzzolanic clay

Quantity of clay from located deposits. Long term research at CRRI has shown that only the right type of clay carefully calcined at an optimum temperature and ground to adequate (minus IS 15) mesh size could yield a highly reactive clay puzzolana. The problem of locating the deposits of such clay has now been solved as a result of the All India Survey of Puzzolanic Clays conducted by the CRRI between 1960–64. The results, as contained in the Special Report No. 1 on 'Puzzolanic Clays of India—Their Industrial Exploitation and Use in Engineering Works', show more than 70 deposits which would yield clays of lime-reactivity higher than 1200 p.s.i. The highest lime reactivity obtained with some of the clays is in the order of 2500–3000 p.s.i. Thus these clay puzzolanas possess lime reactivity several times higher than any other types of known puzzolanas available in India, its value being four to five times the reactivity of bazar surkhis normally derived from brick-bats, and two to three times that of the fly ashes available at present in the country. About 55 million tons of such clays have been located as a result of this survey. Another about 40 million tons of somewhat less reactive clays, that could be used for the manufacture of puzzolanic cement with 20 per cent replacement of cement by puzzolana have also been located.

Desirability of search for more deposits. It is, however, to be remembered that the All India Survey of CRRI has by no means unearthed all the available deposits in the country. In fact it should be considered only as a starting point and further intense search should be conducted by each State with a view to locating additional deposits.

Availability of lime

The importance of lime in the manufacture of lime-puzzolana mixture and detailed knowledge about its availability hardly needs any emphasis. Lime needed for the purpose should be of high grade fat type conforming to the C grade of the IS : 712–1964. It will be difficult to assess the total quantity of such lime available in the country and its production per year. There is no record to give any reasonable figure. The Sub-Group on Building Materials and Manpower, Ministry of Works and Housing estimates approximate production of lime in order of 0.3 million tons a year through a few organized medium scale lime industries alone. Actual figures taking the production by small scale and village level industries into account may be many times more. Besides, the quantity of available lime from industrial wastes, like carbide lime, processed sugar and paper sludge, lime waste from P.V.A. industry etc. that could conform to the

required IS Specification would be quite significant. Requirement of lime in the Fourth Plan has been estimated by the above sub-group to be about 1.4 million tons for building works alone. In case the full requirement of lime for the production of lime-puzzolana mixture is also to be satisfied, a total annual lime production of about 3.5 million tons of lime may be needed. By and large the state of affair in lime production in the country at present is not happy and there is no second thought that the development of lime industry with the acceptance of the same as medium scale industry is of high importance and should be taken up on priority basis.

Manufacture of lime-reactive surkhi mixture

Calcination of clay. The controlled calcination of selected clay to produce reactive surkhi can be effected in either rotary or down draught kiln. For larger units rotary kilns should be used, whereas for the small scale production, down draught kilns may be convenient.

The down draught kilns are essentially ceramic kilns ; but the slight modifications, that may be needed, can be effected without any difficulty whatsoever. Besides both the construction and operation of down draught kiln are simple and the latter does neither necessitate the services of any highly skilled personnel nor the use of strategic material like steel as in the case of rotary kilns for the bulk of the machinery. In view of the above reason down draught kilns are thought to be highly suitable for small scale manufacture of capacity, say, up to 15 tons a day of reactive surkhi or 22.5 tons a day of lime-reactive surkhi mixture.

Grinding of lime-reactive surkhi mixture. The burnt material from both the types of kilns should first be disintegrated in the disintegrator, whereafter it should be fed along with lime in the proportion, 1 lime : 2 burnt material (by wt) to the ball mill. The ground mixture should be of fineness, minus IS sieve 15.

Capital requirements for small scale manufacture of lime-reactive surkhi

Investment for small scale units. Towards capital outlay for units in the small scale industry, the investment requirements for plants of 15 and 60 tons a day capacity have been worked out approximately at about Rs 3.5 and 11.00 lakhs per unit respectively. Besides machineries etc., these figures include working capital, land and civil works.

Suggestions regarding size of units in different States. The size of the unit put up in any area will depend upon the availability of the raw material, the expected period of operation of the unit, the availability of the suitable machinery and technical manpower and the degree of mechanization desired. It is, however, suggested that a greater number of distributed small scale units with a profitably operable range of 50 miles radius for lime-reactive surkhi mixture units coupled with some selected larger units to manufacture lime-fly ash in area favourable for their set up, should be considered. Table 4 gives for different states, suggestions regarding the size of the unit, annual production etc. in respect of the immediate possibility of the manufacture of lime-reactive surkhi mixture.

Table 4—Deposits that could be immediately exploited

(Small size of unit: Capacity about 15 tons of lime-reactive surkhi mixture a day. Medium size of unit: Capacity up to 60 tons of lime-reactive surkhi mixture a day)

State	Puzzolanic clay deposits	Cities & projects around the deposits that could consume the product	Size of units	Production in tonnage of lime-reactive surkhi mixture	Capital requirement (Rs lakhs)
(1)	(2)	(3)	(4)	(5)	(6)
Delhi	Mehpalpur	Delhi, Ghaziabad, Meerut, Hapur, Sonepat, Panipat, Gurgaon, Rohtak, Rewari, Faridabad Bulandshahr, West Jamuna Canal, Gurgaon Canal, Rewari irrigation lift	Small-2	9,000	6.8
Panjab	Sikanderpur	do	Small-1	4,500	3.4
Jammu & Kashmir	Bhadaketar	Jammu, Madhopur, Pathankot, Raisi cements	Small-1	4,500	3.4
Uttar Pradesh	(a) Bansi	Mirzapur, Gazipur, Jaunpur, Varanasi, Mughal Sarai, Churk cement factory	Medium-1	18,000	11.0
	or (b) Lakhanpur	Allahabad, Satna, Rewa, Banda, Satna limes			
Rajasthan	Palana	Bikaner, Rajasthan canal	Small-2	9,000	6.8
Maharashtra	Panhala	Kolhapur, Sangli, Panjim, Belgaon, Miraj, Koyana Stage II	Small-1	4,500	3.4
Gujarat	(a) Wankaner	Rajkot, Morvi, Surendernagar, Jamnagar, Junagarh, Kandla, Khodiar project	Small-1	4,500	3.4
	(b) Eklara	Ahmedabad, Mehsana, Himatnagar, Hatmati project	Small-1	4,500	3.4
West Bengal	(a) Malti	Asansol, Jamshedpur, Dhanbad, Sindri, Purlia, Benkura, Jharia, Ranchi	Small-2	9,000	6.8
	or (b) Patelnagar	Asansol, Burdwan, Calcutta, Gondal, Gomoh, Raniganj, Suri, Dhanbad, Chittaranjan, Bankura, Burnpur, Durgapur, Kulti			
Bihar	(a) Bhagalpur	Bhagalpur, Sahibganj, Monghyr, Rajmahal, Purnea, Saharsa, Mokameh, Kiul	Small-1	4,500	3.5
	(b) Lohardaga	Ranchi, Chaibasa, Waltonganj, Chaibasa & Khalari cements	Small-1	4,500	3.4

Contd

(1)	(2)	(3)	(4)	(5)	(6)
Table 4—*Contd*					
Orissa	Jorbaga	Sambalpur, Sundergarh, Birmitrapur, Bolangir, Raigarh Bhulbani	Medium-1	18,000	11.0
	Koraput	Koraput, Jagdalpur, Vishakhapatnam	Small-1	4,500	3.4
Madhya Pradesh	Gwalior	Gwalior, Morena, Agra, Etawa, Bhind, Jhansi, Shivpuri	Small-1	4,500	3.4
	Chota Bhadora	Jabalpur, Katni, Damoh, Narsinghpur, Sagar, Rewa, Shahdol	Small-1	4,500	3.4
Andhra Pradesh	Bhongir	Hyderabad, Nalgonda, Warangal, Nizamabad Nagarajunasagar	Small-1	4,500	3,4
	Dwarka, Thirmal, Punyakshetra	Guntur, Masulipatnam, Rajamundry, Bluru Bluru	Medium-1	18,000	11.0
	Shekapur	Bidar, Hyderabad, Gulbarga, Golkunda, Sholapur	Small-1	4,500	3.4
	Ralapat	Adilabad, Chanda, Wardha, Akola, Godavari Phase I	Small-1	4,500	3.4
Madras	Sivaganga	Ramnad, Sivganga, Madurai, Karaikudi, Tuticorin	Small-1	4,500	3.4
Kerala	Nilshwar	Cannanore, Mercara, Belur, Calicut	Small-1	4,500	3.4
	Kundara	Trivandrum, Quilon, Nagarcoil, Tenkasi	Small-1	4,500	3.4
Mysore	Ambiganhali	Bangalore, Tumkur, Kolar Krishnagir, Mandya	Medium-1	18,000	11.0
	Ammunige	Mangalore, Mercara, Chickmagalur, Belur, Udipi	Small-1	4,500	3.4
	Tirthhalli	Shimoga, Bhadravati, Sagar, Tirthhalli,Udipi	Small-1	4,500	3.4
		TOTAL	Small-22 Medium-5	1,80,000	125.6

Machinery needed

All the machinery needed could be manufactured indigenously within the country. As mentioned earlier, calcination of clays in small scale level can easily be carried out in the modified down draught kilns. The grinding and blending machineries like disintegrator, ball mill etc. required in the manufacture of lime-reactive surkhi mixtures can also be easily procured. Thus it should be possible to set up a small lime-puzzolana unit within a short period of, say, a few months, once the decision to that effect has been taken.

Costs of production and consumer costs

Based on the pilot plant experience at CRRI in the manufacture of lime-puzzolana mixture using a small down draught kiln for the calcination of clay, certain data for the costs of production have been worked out for

a unit of three 12 ft diam. down draught kilns connected with a central chimney, two disintegrators, 3 ball mills, etc., to produce 15 tons of lime-reactive surkhi mixture a day. The total investment would be in the order of Rs 3.4 lakhs. The costs of production have been calculated at Rs 78 per ton of the bulk material at Delhi. Taking into account a profit of 15 per cent ex-factory consumer costs of Rs 90 per ton of the material in bulk are obtained.

Comparative economy of lime-reactive surkhi-sand mortars over cement-sand mortars

Mix proportions and basic data. In masonry constructions, for mortars of a required strength up to 50 kg./sq. cm. it is usual to employ a 1 : 6 (by vol.) of cement-sand mortar. This is also in conformity with the requirement of the draft IS Code of Practice for preparation and use of masonry mortar, where 1 : 6 (by vol.) cement-sand mortar has been specified for 30–50 kg./cm.^{2} grade mortar. In the case of lime-reactive surkhi mortars, the lime-reactive surkhi mixture : sand ratio for a mortar of 30 kg./cm.^{2} strength and below is 1 :1.8 (by vol.). This ratio for a 30–50 kg./cm.^{2} strength mortar is 1 :1.4 (by vol.). For plaster renderings with lime-reactive surkhi : sand mortars the proportions could be as lean as 1 :2.2 (by vol.).

The savings reported in Table 3 were worked out on the basis of the following basic costs : (a) Cost of cement (to be effective from Jan. 1, 1966), Rs 171 per ton (bulk); (b) Cost of lime-reactive surkhi mixture, Rs 90 per ton (bulk); (c) Cost of sand, Rs 30 per 100 cu. ft.

Economy data from actual construction

Lime-reactive surkhi mixture has been used in a number of construction works in and around Delhi. Following are the two typical examples, where the comparative economy in using this mixture with sand in place of cement-sand mortar were worked out by the construction authorities :

(i) Lime-reactive surkhi mortar and plaster were used in a set of staff quarters in Rohtak by the Punjab PWD. Reactive surkhi for the purpose was supplied by the CRRI on payment and mixed with lime at the work-site by the Department personnel. The haulage involved in carrying the reactive surkhi from CRRI to the worksite was about 40 miles. The nett savings reported in different categories of construction as compared to the conventional cement-sand mortar specifications by the Department on consideration of the transport costs also, are as follows : (a) Saving in the overall costs of brick masonry including costs of bricks (estimated saving in masonry mortar alone = about 5 per cent), 2 per cent; (b) Saving in the overall costs of plaster work, 14.1 per cent; (c) Saving in the cost of pointing compared to lime pointing, 5 per cent;

(ii) About 500 tons of reactive surkhi was purchased by the Indian Institute of Technology, New Delhi from CRRI and used for making lime-reactive surkhi mixture in masonry mortars and plaster renderings for various building construction works inside its premises. The savings reported by the IIT are as follows : (a) Savings in the use of 1 : 2 : 8 (by wt) lime-reactive surkhi-sand mortar using good quality Dehra Dun and Satna lime in place of 1 :6(by wt) cement-sand mortar 24.2 per cent; (b) Saving in the use of 1 : 2 : 12 (by wt) lime-reactive surkhi-sand plaster using

carbide lime (passing relevant IS Specification) in place of 1 : 6(by wt) cement-sand plaster, about 50 per cent.

Recommendations

From what has been already said and the data presented above, it would be evident that the manufacture of lime-puzzolana mixture and lime-reactive surkhi mixture in particular is both commercially and economically feasible. There is very large demand for cementing materials in the country at the present and due to the acute scarcity of cement, many planned works either could not be undertaken at all or had to be stopped or delayed. In the background of far more increased outlay and construction activities during the ensuing Fourth Five-Year Plan, this demand would also obviously increase. Ready-to-use, packaged lime-reactive surkhi mixture as an alternate cementing material would go a long way to serve this demand. It, therefore, needs no more emphasis that lime-reactive surkhi mixture could be produced in different parts of country and marketed at reasonable rates profitable to both the producer and the consumer.

The allied industries that could derive benefit from the lime-reactive surkhi industry are ceramic industry, lime industry, and lime-based industries like carbide, paper and sugar industries. Potential entrepreneurs in lime-reactive surkhi industry could be sought in these groups.

Urgent steps are needed to promote the development of the lime-reactive surkhi industry in the country with the idea of gradually bringing the production to the target of about 4 million tons of the material in course of the Fourth Five-Year Plan. This material could take the place of cement in making building mortars and plasters, foundation concretes, etc. in construction works, thereby effecting considerable savings in cement and ; ome economy too.

As an immediate measure, efforts should be mape to start at least one or two of small scale units in each State. In this context the PWDs and the CPWD could possibly take a very useful lead by setting up small units of lime-reactive surkhi manufacture to cater their own needs.

In order to make the lime-reactive surkhi industry a success an important prerequisite would be the upgrading of the lime industry as an organized medium scale industry. Also limestone for lime manufacture should be classified as a 'major' mineral for the purposes of lease, etc. Lime derived from industrial wastes from the carbide sugar, paper and P.V.A. industries could also be usefully exploited as an additional source of lime by the lime-reactive surkhi industry.

Coconut Pith
Expansion Joint Filler and Building Boards

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Introduction

India produces large quantities of coconut, and is next only to Phillipines. About 1·5 million acres of our land is under coconut cultivation. The elastic corklike material forming the nonfibrous tissue of the coconut husk is commonly called 'Coconut pith'. It is estimated that at present 3,50,000 tons of this material is available annually as a waste product of the coir industry[1], and poses a problem for its disposal. With the advancement of coir industry, the quantity of pith will increase and the disposal problem will intensify. From time to time attempts were made for its utilization in the production of fabricated cement articles[2], roofing boards[3], hard boards[4] and shock proofing boards[5]. Iyengar[6] has reported the preparation of thermal insulating material from coconut pith. It is further learnt from the Coir Board that the Central Food Research Institute has been attempting to use it in the manufacture of some packing material. On account of its poor cellulose content, about 35 per cent, as reported by Prabhu[7] and Pillai and Warrier[8], this material has no place in the pulp industry.

Work at the Central Road Research Institute, New Delhi, was directed towards developing a suitable expansion joint filler board by using coconut pith as the base material. Since the expansion joint filler boards were then imported, the study had the dual objective of finding a cheaper as well as indigenous product. The cement concrete slabs in road pavements, runways and taxiways, bridge decks, etc. expand and contract due to rise and fall in the atmospheric temperature. In order to accommodate such changes, joints having filler material are provided. The basic requirements of such a filler material are: (a) good compressibility, (b) high recovery after compression, (c) adequate resistance to water, (d) resistance to weathering, (e) stability, and (f) adequate strength against handling. The study has since been successfully completed and a process has been developed to prepare coconut pith expansion joint filler boards that would satisfy all the standard requirements. Although during the period between the starting of the project and its completion, a few indigenous products have lately come into the market ; they are high in cost and there is room for improvement in some of them. On the other hand, the production and consumer cost of the coconut pith expansion joint filler, which has been found to pass all the standard specifications, would be significantly lower.

It has been further assessed that with suitable modifications of the process, good quality building boards, thermal insulation boards etc. could be prepared from coconut pith.

Preparation

The raw coconut pith containing about 10–12 per cent of impurities in the form of sand and grit was processed by sieving through IS Sieve No. 60 and washing with water. The cleaned coconut pith was then mixed with animal glue solution (3 per cent animal glue on the weight of pith, made into 4 per cent solution in hot water) in a non-staining tray. As a result of investigations it was found that rubber latex could be used as a binder, but this resulted in segregation. It was, therefore, essential to use some protective agent to overcome this effect. The animal glue in addition to protection against segregation, also imparted some binding property.

The coconut pith mixed with animal glue was then treated with compounded rubber latex, which is a mixture of 28 per cent of rubber latex and 0·25 per cent of vulcanizing paste comprised Z.D.C., sulphur and zinc oxide, both by weight of the pith. The vulcanizing paste was prepared in a 0.12 ammoniacal solution of 3.5 per cent casein by weight of the vulcanizing agents. The mixing process was completed as quickly as possible in order to avoid the clodding of the material. It was than kept in the oven at 50–60°C for 24 hr for curing. The cured material was pressed in a preheated hot press (80°$\pm$5°C) at a pressing load of 75 p.s.i. for 14 min. The prepared board was allowed to dry slowly to avoid warping.

Since the pith was of vegetable origin, the processed board was treated with a solution of 33 per cent 80–100 bitumen in kerosene oil, as a pro tection against microbial attack.

Specimen formulation

The following quantities of the constituent materials shall be required for a board of 3/4″$\times$8″$\times$4″ size:

	Parts by wt
1. Coconut pith	100
2. animal glue solution (4%)	3
3. Rubber latex (60%)	28
4. Vulcanizing paste	0·25
5. Casein	0·009

Laboratory results

The prepared expansion joint filler board was tested as per ASTM Designation D544–49 both before weathering and after weathering. The results are given in Table 1.

Table 1—Properties of expansion joint filler

Sl No.	Tests	Results: Before weathering	Results: After weathering	Requirements as per ASTM standard
1.	Compressive strength (p.s.i)	630	616	100-750
2.	Recovery after compression (%)	91.4	89.9	Not 70
3.	Extension (in inch)	nil	nil	Not 0.25

Field trials

A number of coconut pith expansion joint filler boards prepared at the CRRI have been put to field trial in a cement concrete experimental pavement length on the National Highway No. 2, near Farah (between Mathura and Agra) some 3 years back. The performance in the period under observation has been quite satisfactory.

Cost. The costs of production of the finished coconut pith expansion joint filler board have been estimated at about Rs 14 and Rs 9 per sq. m. for 3/4" and 1/2" thicknesses respectively.

Patent. The process evolved at CRRI has been patented[9] under Indian Patent No. 87958.

Recommendations

(a) On the basis of the results of the present investigation it can be concluded that the wet-retted coconut pith, which has so far been remaining a waste product of the coir industry, offers the possibilities of the utilization of the material for the production of expansion joint filler for concrete pavements and other structures. This process, if commercially exploited, will not only offer a possibility for useful disposal of this material but also produce filler boards significantly cheaper than those available in the market at present.

(b) Besides their use as expansion joint filler for concrete structures, coconut pith boards prepared on suitable modifications in the process, may also be utilized as insulation boards, building boards, packing material, sealing caps, etc.

(c) There is sufficient demand to justify starting of industrial manufacture of boards for use in roads and buildings in the country adopting the above technique. Since the bulk of the material is coconut pith, it is recommended that the manufacture could be started in coconut-growing areas namely, Kerala, Orissa, West Bengal etc.

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Soil as a New Material of Engineering Construction in the Economic Development of India

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With the achievement of independence big construction works are envisaged in the process of rapid industrialization of the country. A large number of houses have to be built in the villages and small towns. Hundred of thousands miles of roads are required to be constructed to open out the backward areas, beside a number of runways. If such constructions were to adopted the conventional specification using cement, stone or burnt brick, the finances required will be so big that it may be beyond the scope of any less developed country to achieve the target. At the same time, the material may not be readily available in quantities large enough to cope with the construction.

It would, therefore, appear very essential that some alternative material of construction should be found out to cope with the rapid process of industrialization.

Recent researches in the domain of soil science have shown that almost all types of soils can be improved in their engineering properties to a varying degree, depending upon their composition. A brief summary of the proven results of research in soil mechanics is reported here.

Compacted soil

It has been shown that almost all types of soil improve in their strength, when compacted at controlled moisture to a high density. In the dry condition the strength of compacted soil will be about 200–300 lb/sq. in. which will further increase if it is mixed with soft aggregates in the ratio 2 parts of soil and 1 part of aggregate. In the wet condition the bearing capacity of compacted soil is equivalent to a CBR of 8–10 per cent. The strength can further be increased to some extent both in the dry and wet conditions if the soils are properly blended before compaction with other local soils to improve their grading.

Stabilization of soil with cement

The resistance of compacted soil, to softening effect of water, can be considerably increased further by stabilization with cement. With a concentration of about 2·5 per cent cement, the blended soil when compacted to high density will give a strength of about 250 lb/sq. in. The strength further increases with the increase in cement content.

In case of very clayey soils it has been found economical to first treat the soil withsmall concentration of lime, before stabilization with cement.

Inferior aggregates

There are large deposits of inferior aggregates which have not been fully exploited on account of the fact that due to haphazard use certain failures have occurred in some of the initial trials. It has now been shown that inferior aggregates after proper testing can be used into the lower layers of the road pavement in place of rubble soling. The inferior aggregates found mixed up with plastic fines are generally rejected for use in road construction. These can also be economically improved with lime or cement resulting in high soaked CBR—as high as 100 per cent in some cases.

Soil gravel mixture

There are large deposits of soil gravel mixtures in the country which are being used as such. It has been found that if such gravelly meterial is properly graded with respect to their coarse and fine fractions, there is a considerable improvement in their engineering properties which make them strong enough for use in road bases.

Based on the information given in the foregoing paragraphs, the soils and other inferior aggregates locally available, can be scientifically improved to economize on the cost of following types of projects :

Roads

Since the number and weight of the vehicles using the roads today have increased considerably, the thickness adopted in the past are in adequate ; in addition, some of the areas are getting waterlogged requiring still higher thicknesses of the pavement. According to the Twenty-Year Road Development Plan for 1961–81, the estimated thickness of pavement is fairly high as per details given below:

	Total mileage during the plan	Thickness of crust (in.)
National Highways	18,200	30
State Highways	35,000	30
Major District Roads	54,800	28

It will appear that if such constructions were to be carried out according to the conventional method using stone boulders or burnt brick in lower layers and stone metal of $1\frac{1}{2}''$ size in the upper layers, the cost of such road would be very high indeed. The same thickness can, however, be built up, without affecting the scientific design, by replacing the lower 18 in or so of the road crust of hard stone with soil compacted at controlled moisture. Replacing the lower 18 in. layer of stone boulders with compacted soil at almost 10–15 per cent of the cost of the stone, for a length of over a lakh of miles will result in huge saving which might be of the order of a couple of hundred crores of rupees.

At places, where stone is costly, the base course of the crust which is generally built up with hard stone, can also be replaced with inferior aggregates, soilgravel mixes, or soil stabilized with cement. This will further cut down the cost.

The Road Development Plan, further provides a length of 1,17,000 miles of other district roads and 68,000 miles of classified village roads. If these roads were to be built in conventional specification, it will probably

be found economically impractical. Such roads can still be constructed by building up the crust either with soil gravel or inferior aggregate or stabilized soil. By adopting all these techniques, the saving on the whole plan will run into a few hundred crores of rupees, which is a very substantial saving indeed.

Runway construction

Present day runways are about 2 miles in length, and about 200 ft in width. The specification for flexible pavement which is about 45 in. thick consists of hard stone throughout the depth. Even when concrete pavement is adopted, there is a provision of 12–18 in. of stone water bound macadam before concrete slabs are laid. Recent field trials by Central Road Research Institute on the construction of a runway using flexible design have shown that the lowermost 12 in. layer can be built up with compacted soil alone and the middle layer with soil stabilized with cement except for the top 6 in. which are required to be built up in hard stone. Such specifications, besides being scientific in design, will reduce the cost by almost 50 per cent (saving of about Rs 30–40 lakhs per runway).

Even when cement concrete specifications are adopted, the base need not be built up with hard stone metal, as is practised now. This could be built with local soil stabilized with about 3–4 per cent cement instead of carrying stone metal over long distances, as high structural strength is not required. It is known that many constructions were held up for want of hard stone, which could not be carried in time. It would, therefore, appear that the use of soil or other inferior aggregates in the construction of runways, will not only reduce the cost but will also give more out-turn which is of still more importance in the days of emergency.

House construction

Permanent. Permanent houses are generally built using burnt brick and cement. On account of acute shortage of cement which may persist for quite some time to come, the construction of houses in suburbs is practically stopped.

Research work carried out in India has shown that a compressive strength of about 300 lb./sq. in. can be attained by compacting local soil with about 4 per cent cement even under soaked conditions. This strength should be satisfactory for single-storey houses which are mostly built up in suburbs, villages and farms. The use of such material will reduce the cost of the wall by almost 50 per cent besides offering better insulation against heat or cold than brick. The saving is based on the practical experience of building 4000 houses in India using soil cement in the walls. The houses are about 16 years old and reported to be giving satisfactory service.

Semi-permanent village houses. The temporary houses as built in villages today, require very frequent maintenance and takes much of the time of the farmers which can be usefully utilized elsewhere. Since compacted soil has reasonably high strength, the same can be used for building houses. To retain strength of compacted soil, even during rains the walls can be plastered with a water-proof mud rendering, which has been recommended as a result of comparative study conducted by the National Buildings Organization.

The use of locally available soil as a material of engineering construction besides huge reduction in the cost of the projects, will also reduce transport for carriage of coal, petrol, lubricants etc.

Utilization of Results of Road Research

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The provision of an adequate road system, in a vast country like India. will need large financial resources which are beyond the present financial capacity of the country. On the other hand, it is necessary that road construction should keep pace with other developments, which are fast generating more and more road traffic. In the recent past, both the number and the weights of vehicles using the roads have increased very considerably, with the result that the thicknesses of the road crust normally adopted, are inadequate and are resulting in progressive unevenness and ultimate failure of existing roads. The problem from the financial angle has consequently become extremely difficult, inasmuch as, not only are long mileages of road to be provided but also the thicknesses required now are much greater than in the recent past.

It is therefore, obvious, that the cost of construction should be reduced to the barest minimum, so as to go on providing maximum possible length of road with available finances and to maintain it without basic deterioration.

To achieve this objective of economizing on the construction and maintenance of roads in a country like India with the available financial resources, it is imperative that all efforts should be made to utilize the modern researches in road design and construction and also to utilize to the maximum possible extent the locally available cheaper materials for their construction.

The paper is devoted to a brief description of techniques evolved as a result of research and the problems involved in large scale implementation of these techniques in construction and maintenance of roads in the country. Some of the new products and materials evolved by research and some suggestions for their large scale manufacture are also discussed.

Techniques

Modern research on road and runway design and construction, both in India and abroad, has resulted in the development of new techniques which offer huge savings in cost of construction without in any way compromising with the scientific requirements of design. Some of the important techniques are given below:

(i) With the present day traffic, it has become necessary to provide pavement thickness of the order of 20 to 25 in. as against 7 to 9 in. provided in the past. As a result of investigations, it has been established, that by scientifically controlled compaction, the local soil itself could replace stone

or brick in the lowest 12 to 15 in. of the total pavement thickness required, at a fraction of the cost. This simple idea of the replacement of brick or stone, with scientifically compacted soil as a construction material with the required strength and stability values, is considered to be an important 'break through' because of the very fact that it is a simple, inexpensive and easily applicable, and could reduce the road construction costs enormously.

(ii) A new method of road construction has been evolved utilizing blended local soils along with cheap low grade local aggregates, which produces a road crust at a cost of only 45 to 55 per cent of the traditional water bound macadam and is usable for many thousands of miles of roads, carrying medium traffic in comparatively dry areas.

(iii) Specifications have been worked out for the utilization, in road construction, of low grade aggregates like laterite, kankar moorum, etc., which have so far been looked upon with suspicion. The increased use of such cheap local materials in road construction, in place of stone metal, will result in large savings in cost and transport.

(iv) A method of economic stabilization of black cotton soils with a small percentage of lime, has been advocated, for use as subbase, to prevent the deterioration and the high cost of maintenance of roads, in areas abounding in such bad soils.

(v) As a result of long experimentation, it has been possible to recommend that the general period of renewals of bituminous surface dressing of almost the entire black top mileage of the country, can be increased from 3 years as now practised, to as much as 5 years, resulting in very substantial savings in maintenance expenditure.

(vi) A method has been evolved for cheapening the cost of concrete pavement construction, by introducing burnt brick in the neutral axis region, where the stresses are low enough. Results of laboratory and field experiments, both on plain and brick sandwitched concrete, have shown that the cost of construction can be reduced by about 15–20 per cent without impairing the strength requirements.

(vii) In the arid zones of Rajasthan, there is need to stabilize the locally available fine drift sand for use in road construction as a cheaper substitute for stone, which has to be imported from great distance, and water for its consolidation, which is scarce. A method of stabilization of this ungraded fine sand, with bitumen, has been worked out by the use of locally available soft kankar as a filler.

Implementation

The question of utilizing new techniques of road construction evolved as a result of research, and thereby effecting economy in the cost of road construction and also increasing the durability of roads, has been under consideration of the Government of India for many years. A Committee of the Panel of Scientists appointed by the Planning Commission recommended in December 1956, that in order to bridge the gap between research and the application thereof, Assessment Committees should be set up preferably under the auspices of the All India technical bodies to evaluate the results of research, to decide on large scale trials of construction work, and to make allocations for these works from the funds to be provided for the purpose. As far as road research goes, the question was examined by the Government of India in consultation with the State Governments

and a Central Assessment Committee under the aegis of the Indian Roads Congress was constituted by the Ministry of Transport and Communications (Department of Roads Wing). Funds were earmarked for large-scale experimentation of road construction and to popularize new techniques evolved as a result of laboratory research. A sum of Rs 75 lakhs was set apart as a sort of 'Risk Fund' in the Central Sector of the Roads Programme of the Third Five-Year Plan (of which 33 lakhs was to be used for the purchase of special machinery) for covering risk of losses and extra expenditure on approved experimental work and the States were requested to devote one per cent each of the provision for road development in the Third Five-Year Plan for schemes of experimental specifications and new techniques to be applied instead of normal conventional specifications and techniques, on selected road lengths of road projects included in the Third Five-Year Plan of the States.

As a result, a number of States have agreed to adopt new techniques, but the progress on the whole is rather unsatisfactory. The slow progress could be attributed to the following facts.

(i) Road construction is a State subject and it is not easy for the Centre to enforce a decision.

(ii) The Chief Engineers being heavily occupied with many jobs are not in the mood to try new techniques requiring more technical attention.

(iii) The scientific backing required is not readily available in most States.

The remedy would appear to lie in proper implementation equally by the Centre and the States, of the recommendations made by the Planning Commission vide their circular letter No. 7/3/62 RSR dated December 12, 1962 addressed to the Chief Secretaries of all State Governments/Heads of Union Territories, which are repeated below and which could usefully be once again brought to the notice of the authorities concerned by the Planning Commission.

"(*a*) *Lack of trained staff*—The subjects of Highway Engineering and Soil Mechanics in the scientific sense, have been developed only recently. The engineers by and large have therefore, did not have the opportunity for a formal university training in these subjects. A few of the practising highway engineers have been sent abroad from time to time to pick up the latest practices, but the bulk of them have been so busy with the heavily increased tempo of work, that it has not been physically possible for them to keep pace with the fast developing subjects, while having to discharge the extremely heavy responsibilities falling on their shoulders after independence.

Furthermore, even though the post-graduate Highway Engineering courses have been in operation in some Universities in India for about five years now, there is only a very small percentage of recruited young engineers in Highway Departments who possess such post-graduate qualifications, the bulk of them still being ordinary graduates in general Civil Engineering, where Highway Engineering as such, understandably finds a very small place.

Being alive to this deficiency, the Central Road Research Institute have with the support of the Indian Roads Congress and the roads Wing of the

Ministry of Transport and Communications, recently started separate Refresher Courses for senior and junior Highway Engineers.

The response so far has been fairly encouraging, but it is felt that it should grow much bigger than at present, if the programme is to assist in the modernization of road construction and design methods within reasonable time.

(*b*) *Lack of testing facilities*—Out of 22 States and centrally administered areas, only 9 States have got laboratories where facilities for testing soils and materials are available.

A scheme for the setting up of Testing and Control Laboratories, was prepared by the Central Road Research Institute in 1957, and the Ministry of Transport and Communications undertook soon after to give financial aid in this respect to those states which made a request for it. But under this arrangement, out of the many administrations which did not have testing laboratories, only one or two have made an official approach, even though the Chief Engineers all seem keen to have them.

Some States seem to have difficulty in providing the necessary staff etc. This is, however a facility which must be provided before any modernization and consequent economies can be expected.

(*c*) *Lack of equipment and machinery*—There seems to be an erroneous impression that no work on soil stabilization can be done, unless special equipment for mixing and compaction is first provided.

Whereas it is true, that mechanization of the various processes involved will not only improve the quality of work, but also reduce the cost of construction, there seems to be convincing evidence available in the form of actual work executed that soil stabilization can be carried out effectively and cheaply even with manual labour if only trained staff is available for quality control.

Consequently, whereas efforts should no doubt be made to mechanize construction to the extent justified, the putting into practice of soil stabilization techniques, cannot justifiably be kept in abeyance, till it becomes possible to provide machinery.

At a pinch, the available power rollers can be used double shift to cater to the requirements of soil compaction, in addition to the consolidation of stone, and light bullock-drawn sheeps-feet rollers can be used also, for compaction of the ordinary types of soils.

As a condition for the International Development Association loan to India for roads, the use of up-to-date design and construction methods including employment of heavy machinery is visualized. This is a welcome opportunity for introducing new techniques in high class roads and using machinery for getting improved quality of work. It is hoped that full use will be made of existing high level facilities and that work will be carried out by Indian agencies with a view to training Indian personnel as much as possible, in the use of modern methods of design and mechanizd construction.

As an immediate measure, the Ministry of Transport and Communications have allocated a sum of Rs 33 lakhs for purchase of a central pool of machinery of all kinds, to be placed under the control of the CRRI for organized use in projects by different States, with a view to making their

staff conversent with the use of machinery, so that the change over from man to machinery may be as smooth as possible. It is hoped that his machinery will be obtained at an early date.

(*d*) *Risk of failure*—Even after a new process or technique has successfully passed through the laboratory stage and small scale field exprimentation, an element of risk, however small has still to be faced in so far as it is likely, that in the utilization of the technique in routine construction, a failure may occur here and there. This risk of failure has had till recently to be indirectly carried by the Chief Engineer-in-Charge, as being the technical authority responsible for the project concerned. This had been causing an understandable hesitation in the minds of Chief Engineers, to apply new ideas and techniques in routine construction, with the result that application could not keep pace with research.

Having ultimately accepted the principle, however, that Government being the sole beneficiery from research on roads, should legitimately accept financial responsibilities involved in the full scale development of new technique, the Central Government in the Ministry of Transport and Communications have at the instance of the Planning Commission created a 'Risk Fund' of Rs 75 lakhs (out of which Rs 33 lakhs is earmarked for purchase of machinery) for the purpose, in the Third Five-Year Plan. An Assessment Committee of Experts has also been formed by the Central Government in consultation with the Indian Roads Congress to advise the Government in this respect. The Assessment Committee has already held three meetings and has accepted the construction of over three hundred miles of road in five States according to the various recommended techniques.

The idea is that according to each new technique, which is considered fit for exploitation in India, a sufficient length of road should be constructed in each State, under financial protection from the Centre, to create enough confidence among the local engineers, to justify their being expected to use the technique concerned in routine construction thereafter.

The point that emerges from this is that it should be made possible to 'underwrite' the risk of failure in sufficiently long lengths of road built according to recommended techniques in each State, against the risk fund of Rs 42 lakhs. It may be argued that the sum of Rs 42 lakhs will allow of only a ridiculously small mileage of road to be constructed against each technique in each State. But considering that this amount is only a 'risk fund', it would not only be unnecessary but also incorrect from the financial angle to increase it just for that reason.

Since the techniques will already have undergone careful examination and experimentation at the laboratory level and the semi-field scale level, the risk of failure is likely to be very small indeed and as such, the value of work which can be safely underwritten against the amount of Rs 42 lakhs, will obviously be many times that amount. Consequently, the sponsoring of 'protected' projects, each of a large enough denomination, against each new technique and in each State, without increasing the present risk fund of Rs 42 lakhs, may present the difficulty, if a reasonable risk of failure is assumed on the principle of insurance.

Also, since the States will be using the new techniques only on the roads already accepted for the Third Five-Year Plan, and since the risk of failure will be fully covered, there could be no sanctity attaching, from the point of

view of the States, to the upper limit of 1* per cent of the Third Plan provision under roads, sa far ao the expenditure on 'development' of research is concerned.

Encouraging rapid utilization of results of research

In view of what has been said in the foregoing pages, the following recommendations would, in the interests of the rapid utilization of the results of road research towards the much needed economy, appear to require close and careful consideration, at the hands of the Central and State Governments.

(i) *Refresher Courses*—In order to ensure that the senior as well as the jounior Highway Engineers get as soon as possible, an opportunity of bringing themselves up-to-date with the lastest practices in Highway Engineering and soil Mechanics, at least one nominee from each department, including the State and Central PWD's, the PWD's of the centrally administered areas, and the Roads Wing of the Ministry of Transport and Communications, should be sent by turns for each of the two separate courses for senior and for junior engineers at the Central Road Research Institute.

It will help the departments in making out programmes before hand and to avoid late arrivals for the short courses, if a decision at the policy level can be taken by the Governments concerned once for all, to depute at least one officer for each course.

(ii) *Testing laboratories*—The State Governments, the Central PWD, and centrally administered areas, which do not have testing and control facilities in their highway departments, may be prevailed upon by the Central Ministry of Transport and Communications to sanction laboratories against financial assistance from the Centre, which may be specifically mentioned. Any technical assistance required could be provided by the CRRI.

(iii) *Equipment and machinery*—A permanent committee consisting of representatives from the Ministry of Commerce and Industry, the Ministry of Transport and Communications (Roads Wing), the Indian Roads Congress, the CRRI, etc. should be set up to plan and to arrange for the coordinated production of road making machinery within the country, and to review the position from time to time.

The machinery worth Rs 33 lakhs, for which allocation has already been made by the Ministry of Transport and Communications, should be purchased as quickly as possible in consultation with the CRRI.

(iv) *Risk fund*—The Assessment Committee appointed by Government of India, may be asked to recommend a reasonable percentage of risk for the type of 'development' work they are recommending, so that it may be possible for each State to carry out enough work against each new technique under 'protection' to give sufficient training and confidence to the local staff, to adopt it in routine construction.

This Committee may be specifically charged with the responsibility of keeping Governments and the Planning Commission informed as to whether the 'development' of new techniques is proceeding at a satisfactory pace.

*An adhoc limit suggested in the first instance.

(v) As the bulk of the work under the 'Risk Fund' in the next many years will consist of the use of soil as a construction material, each State should have one of the working divisions allocated to soil stabilization works entirely. The testing and control laboratory should be placed under this division, and all soil stabilization works in the State placed in its charge.

This Division should also be charged with the responsibility of carrying out a detailed survey of local materials, usable in road construction as cheaper substitutes for traditional materials.

The CRRI could undertake the training of staff for this purpose, and should provide any further technical assistance required, through its extension services. The Division should, while carrying out construction work, also systematically train the staff at lower levels, both in theory and practice.

(vi) It seems necessary at this stage, that the CRRI should enlarge their 'extension service' in order to provide expeditiously, the much needed 'on the spot' technical advice and assistance required by many States.

This could be done most effectively in collaboration with the liaison service of the Roads Wing, already in existence in the country, in connection with the National Highway System.

(vii) To derive full advantage of the high level specialist staff provided at the CRRI, for some years at least, the design and specifications of the major road works on the National Highways, should be entrusted to, or in any case finalized with the concurrence of the CRRI and Consulting Engineer, Roads, as a matter of routine practice. The idea is that complete project reports will be prepared, and these will not only ensure that the latest practices are being followed on the National Highways at least, but the ideas will also gradually spread out to the State and other Highways, to the steady improvement of efficiency and economy.

In conclusion, it is to be hoped that if due attention is given to the above suggestions by the various Governments, it should be possible before long to effect large savings in construction costs of roads as a result of the substantial outlay on road research, and also to make it possible to increase appreciably the mileage of road that can be provided with the funds thus saved without loss of efficiency".

Quality control

Another aspect of road construction which is causing concern is that sufficient attention is not being paid at present to exercising judicious quality control on construction for highway and air-field pavements. It is fully realized that small expenditure in quality control work brings in rich dividends, since when it is exercised in a proper manner, it results in both economic and better construction. Thus it is imperative that due consideration is given towards exercising effective and efficient quality control on all road construction jobs. Further, on certain types of constructions, such as superior bituminous carpets comprising dense bituminous mixes, and cement concrete pavements, it would be advisable if the construction is mechanized. These expensive surfacings give best results only when laid mechanically with effective quality control. For this, it would be essential that the indigenous manufacture of the required plant and machinery should be taken up without any further loss of time.

As far as production of road equipment and machinery is concerned, it is suggested that it is high time to initiate a coordinated scheme for producing indigenous know-how on the design and manufacture of such machinery. This can probably be done by the CRRI in collaboration with the CMERI and the Industry in close coordination with the Ministry of Industry and Supply. The main idea would be to import selected pieces of machinery from abroad, and to produce an Indian equivalent, by a systematic reduction of imported components.

Products and Materials

Reactive surkhi

Fundamental and applied research work of far-reaching importance on the use of puzzolanic clays has been completed. It has been found that only certain clays having specific mineral compositions are suitable for making reactive puzzolanas and that each type of suitable clay has its own optimum temperature at which it should be burnt to yield a surkhi with maximum reactivity. As a result, a new material 'Reactive Surkhi' has been sponsored and All India Survey has been completed to locate natural deposits of suitable clays from which this material can be manufactured. The material can replace about 20 per cent of cement in cement concrete, producing a cheaper and better concrete. It can also be used in combination with lime and sand, as an alternative for cement sand mortars in masonry construction and plasters. The use of this material would not only meet the shortage of cement in the country but would also achieve some economy in the construction cost. The introduction of this material calls for the development of a new industry for the scientific manufacture of puzzolanic surkhi and ways and means should be found out to provide special inducements to the manufacturers to encourage the rapid growth of puzzolana industry. The Government should also take immediate steps towards the scientific development of various puzzolana resources in the country and for development of indigenous machinery for manufacturing the material. Similarly, manufacture of puzzolanic cements by the cement industry should be encouraged.

The following recommendations of the Symposium on Puzzolanas, their Survey, Manufacture and Utilization, organized by the Central Road Research Institute (December 1964), should be specifically looked into by the Ministries concerned for proper implementation :

"1. That the Planning Commission may be requested to convene a meeting of the Ministries of Industries and Commerce, Works and Housing, Irrigation and Power, and also Defence, Railways, Transport, Public Sector Undertakings as well as some connected research organizations, to make concrete proposals to Government for immediate steps to be taken towards the scientific development of various puzzolana resources in the country for use in combination with cement and lime and for development of indigenous machinery for the purpose.

2. That the Ministry of Industries and Commerce may urgently consider the question of upgrading the lime industry in India as a medium scale industry coming under the purview of the Technical Development Directorate of that Ministry. Also that limestone for use in manufacture of lime should be classified as a 'major' mineral for purposes of lanse etc.

3. That the Ministry of Works and Housing may urgently convene a meeting of the representatives of the National Buildings Organization, Central Public Works Departments, State Public Works Departments, Railways, Enginering Wing of the Defence Establishment, Indian Standards Institution etc., including some experts to determine modifications in the existing specifications for masonry, concrete and plaster works etc., to allow the use of puzzolana in such works.

4. That the Ministry of Industries and Commerce may consider ways and means of providing special inducements to the manufacturers, to encourage the rapid growth of puzzolana industry.

5. That the Indian Standards Institution may look into the question of providing necessary standards for proper exploitation of different types of puzzolanas.

6. That further research on puzzolanas, specially in regard to their use in reinforced cement concrete work should be actively pursued by research laboratories".

Expansion joint filler from coconut pith

Nearly 35,000 tons of coconut pith, which is a byproduct of the coir industry, goes waste every year. Studies towards binding coconut pith in sheets, which can be used is expansion joint filler for concrete roads, have successfully been completed. A suitable process has been developed whereby the coconut pith is mixed with a binder, cured at high temperature and hot-pressed. The finished material fulfils all the requirements of standard specifications for this material.

A special incentive is required to be provided for industrialists to venture into the manufacture of this indigenous material.

Low temperature tar

Low temperature tar is a byproduct obtained during the low temperature carbonization of coal, usually of inferior grade, to produce domestic smokeless fuel. The economy of this low temperature carbonization industry is closely linked with the profitable utilization of the byproduct tar. With the Lignite project in the South going into full production together with other commercial undertakings producing smokeless fuel, it is estimated that about 5 million tons of this tar may be available in the country within next decade or so. Methods have been developed to produce suitable road binders from the low temperature tar and the binders satisfy nearly, the specifications laid down by the Indian Standards Institution for high temperature road tars, and their properties have been found to be satisfactory. It is but obvious that development work on this product must follow a full scale commercial production. In order to give a fillip to the industry in the initial stages, the processed tar can be used in surface dressing or in dense tar surface with lime as a filler in roads which do not carry a very heavy traffic, such as minor district roads. A further possibility of utilizing the tar in the present stage would be to use it in soil stabilization. Small units for distillation and processing of the tar can be set up as supplementary or as ancillary to the major low temperature carbonizing industry.

Modified tars

Extensive laboratory and field work, both abroad and in India, has been carried out to study the mechanism of hardening resulting in the loss

of life of tar surfacings. Research work has indicated that hardening of tar is more due to polymerization and evaporation of the oils than due to oxidation. This obviously suggests the development of tars blended with high boiling point oils. This leads to fixation of the ratio of pitch to anthracene oil in the tar and it seems that a tar of pitch anthracene ratio of about 3 to 4 would be suitable. An alternative method of improving the durability of the tar would be to use bitumen pitch blends ; the proper proportions would obviously depend on the type of pitch and the bitumen used. At present in India there are not many industries which manufacture such modified tars or tar bitumen blends. Either this can be produced as an auxiliary of the major manufacture of the residual product or as a small industry working in that complex.

Sealing compounds

Only very few sealing compounds used for sealing joints in concrete floors and road slabs, are readily available in the market. Till a decade or so back some of the compounds were being imported inasmuch as only the imported compounds had the needed durability, elasticity and resistance. A product has been developed, as a result of research, comprising asphaltic bitumen and mineral filler together with a gel, so as to make the compound resistant enough. It has been observed in the field trials that it gives a long life and useful service. Small industries could very well be set up to manufacture this compound to meet the requirements of road and building engineers.

Anti-stripping agents

Anti-stripping agents are chemicals added to bitumen to prevent stripping. These additives enable the bitumen binders to form a quick and stable adhesion with wet, dirty and difficult stones from which the coated binder gets stripped in adverse climatic conditions. As a result of investigations, a suitable additive has been evolved which can be directly incorporated into hot bitumen. There are number of compounds and methods by which stripping can be eliminated. These compounds can be anionic types, such as soaps of heavy metal or cationic types such as quaternary ammonium. There are not many industries at present which manufacture these products. Some chemical industries which deal with the base material can profitably develop ancillary units to produce this compound for the use of road engineers, thereby facilitating a prolonged life for road surfacings.

Jet blast and full resistant binder

A problem that has been facing the air field engineers is the disintegration that takes place on bituminous runways as a result of jet blast and solvation in jet fuel oils. A number of doped binders have been developed in the West, using epoxy resin or synthetic rubber. Since epoxy and synthetic rubber are either to be imported or are very costly, a doped tar has been developed in the country which can very well be used as a binder in a dense tar surfacing. This doped tar, when fluxed with anthracene oil, can very well be used as a road binder having very much improved properties. It can also be used in the form of a soft pitch for the manufacture of sealing compounds and when suitably blended for the manufacture of pre-fabricated bituminous surfacings for the army. These products are jet fuel resistant and as such may be considered very good construction materials in forward areas and in runways. The product is patented and any small industry which develops it can be sure of good dividends.

Some Thoughts on Bituminous Materials in Road Construction

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Almost all the asphaltic bitumens manufactured as a residual product in the petroleum industry in India are used mainly for road making purposes. A major portion of the crude tar produced in the coke ovens of steel works is used as fuel except for a very small quantity which is converted into road tars of various grades. As against this is the picture that only one-fifth of the entire road mileage of the country is surfaced with a black top. And, in the background of the rapid industrialization that is taking place and in which context an extensive road construction programme is also envisaged, one can see the need for an augmented supply of road binders and/or to improve the durability of such materials.

In the first group comes the low temperature tar which is obtained as a byproduct during the low temperature carbonization of inferior coals. The economy of this low temperature carbonization industry is closely linked with the profitable utilization of the byproduct tar. With the Lignite project in the South going into full production together with other commercial undertakings producing smokeless fuel it is estimated that about 5 million tons of this tar may be available in the country within the next decade or so.

This tar, as it is, has a relatively high percentage of phenols as well as paraffins. In addition, its consistency is so thin that it requires further processing and treatment for use as a road tar of proper viscosity and grade. Research on the processing has been on hand in a few laboratories in the country and the earliest method was to produce an air blown tar, which not only increased its viscosity but also produced more or less a preoxodized tar. Another method was to distill the tar to a suitable pitch fraction (80°C.R&B softening point) and to blend it with sufficient quantity of tar oils of varying boiling points to yield a road tar. A modification of this method was to blend the tar pitch with asphaltic bitumen so as to yield a good road binder. When the tar contains a high percentage of wax, chemical treatment and distillation in the presence of a catalyst is reported to yield useful tars for road purposes.

Using some of the tars, a full scale test road was laid by the Central Road Research Institute. A series of surface dressings as well as pre-mix carpets was laid. It was found that the former specifications stood much better than the latter probably owing to the greater thickness of film and lower viscosity of the binder. The durability of the tar as studied in the laboratory was not comparing very favourably with the high temperature tars. But there are indications that it can be improved. It is obvious that development work on this product must follow a full scale commercial

production of the base material. And in order to give a fillip to the industry in the initial stages, the processed tar can be used in surface dressing or in dense tar surfacing with lime as a filler in roads which do not carry very heavy traffic, such as minor district roads. A further possibility of utilizing the low temperature tar in the present stage would be to use it in soil stabilization. Small units for distillation and processing of the by-product tar can be set up as supplementry or as ancillaries to the major low temperature carbonizing industry. Though at the outset this may not nearly be a first rate product, yet in years to come with the experience gained from the performance and behaviour of low temperature tar surfacings the needed requirement of greater durability can be built into the tar by the laboratory technician by suitable minor modifications during the processing of the tar as such or in the technique of laying it in the surfacings.

Closely following this is the improvement in the development of the already existing road binders. Out of the two, namely high temperature road tars and asphaltic bitumens, the former has much lower service life than the latter. Although, as stated before, most of the coke oven tars are used for purposes other than road constructions, any improvement in the life expectancy of a tar surfacing would mean much in increasing the low mileage of black topped roads in the country. Extensive laboratory and field work both abroad as well as in India has been carried out to study the mechanism of hardening resulting in the loss of life of tar surfacings. Research work has indicated that hardening of the tar is more due to polymerization and evaporation of the oils than due to oxidation. This obviously suggests the development of tars blended with high boiling oils. This leads to the fixation of the ratio of pitch to anthracene oil in the tar. Whereas the higher the pitch-anthracene ratio, the greater would be the rate of setting (a quality needed during road construction), a higher pitch content would mean an early brittleness of the surface. A reasonable compromise seems to be to have a tar of pitch-anthracene ratio of about 3 to 4 as borne out in the field test track of the CRRI. An alternative method of improving the durability of the tar would be to use bitumen pitch blends, the proper proportions for which would obviously depend on the type of pitch and bitumen used, whereas with a low temperature crude, a higher percentage of the pitch seems to be tolerated in the blend, in the case of the high temperature pitch it is restricted. At present in India there are not many industries which manufacture such modified tars or tar-bitumen blends. Either this can be produced as an auxiliary of the major manufactures of the residual product or as a small industry working in that complex.

Although the manufacture and production of asphaltic bitumen is of minor importance in the refineries with the result that the quality needed can be met only to the extent that it does not offset the economic production of other major products of the industry, the road engineer demands ease of workability and durability as being essential proportions of the products. Durability, being inherent in the material, workability can be modified to the needs of the job. A straight-run bitumen is made easily workable by heating it to the appropriate temperature consistent with viscosity requirements. Its rate of setting at any given climatic condition, however, depends on the crude or the method of manufacture. For example, because of the paraffinic nature of the crude, bitumen obtained as a residue during the refining of the Indian crude oils contains relatively a higher percentage of wax than those from the Middle-East. To lower this, partial air blowing

of the residual bitumen is resorted to, yielding thereby a bitumen of low ductility. Low ductility by itself may not be a deterrent for its use, but, it is found that some of the bitumens so obtained are more susceptible to temperature changes affecting thereby the property of setting of the binder in its field application. Though at present this product is used only in restricted quantities and areas, with increase in the production of binders from Indian crudes it is likely that this problem may become more prevalent. Forecasting this and to be ready to meet the problem will obviously rest on the shoulders of the binder manufacturing concerns inasmuch as the cost of modifications, if any, needed in asphalt production, will have to be studied in conjunction with the overall economies involved in petroleum refinery as a whole. A pilot plant scheme worked on cooperative basis by CRRI and IIP and the binder manufacturers perhaps would go a long way in meeting the challenge if and when it occurs.

Another road binder, which is being manufactured only by two or three firms and that too in small quantities in the country is bituminous emulsions. Although the material has a wide range of application, its high selling price has been a deterrent against its wide usage. One way by which it could be made cheaper is, if supplies are made in bulk, thereby eliminating the cost of the containers which forms nearly 40 per cent of the total cost. Bulk supply could be effected by means of bulk tank lorries and mobile storage drums. This would entail the setting up of small emulsion manufacturing plants in different parts of the country suitably located to shorten the lead for transport. The technique of its manufacture not being complicated quite a few more enterprises can be set up profitably catering to the various regions in the country. The need for this may be imminent when one considers the fact that this material can be of immense value to the army engineers in the front.

As mentioned earlier, a small percentage of the residual bitumens manufactured is used for other industrial purposes. One such industrial product is a sealing compound, used for sealing joints in concrete floor and road slabs. Although there are quite a number of compositions in patent literature, only a very few are readily available in the market. Till a decade or so back, some of the compounds were being imported inasmuch as only the imported compounds had, needed durability the elasticity and resistance. A product has been developed in the CRRI, comprising asphaltic bitumen and mineral filler together with a gel, so as to make the compounds resistant enough. After a number of field trials, it has been observed to give a long and useful service and small industries can very well be set up to manufacture them to meet the requirements of road and building engineers.

Another problem that has been facing the airfield engineer is the disintegration that takes place on a bituminous runway, as a result of jet blast and solvation in jet fuel oils. A number of doped binders have been developed in the west using epoxy resin or synthetic rubber. Since epoxy and synthetic rubbers are either to be imported or very costly, the CRRI has developed a doped tar which can very well be used as a binder in a blast and fuel resisting dense tar surfacing. This doped tar comprises a heavy coke-oven tar pitch. When flued with anthracene oil to suitable consistencies it can very well be used as a road binder having very much improved properties. It can also be used in the form of a soft pitch for the manufacture of sealing compounds and when suitably blended for the manufacture of prefabricated bituminous surfacings for the army. These products are jet fuel resistant and as such may be considered as very good construction

materials in forward areas and in runways. A patent for the same has been filed by the CRRI and it is felt that it can be exploited fully for producing another runway construction material and any small industry which develops it can be sure of good dividends.

Though not bitumen based, but closely allied to the tehnique of bituminous road construction is the industrial product known as surface active additives. These additives enable the bituminous binder to form a quick and stable pitch together with a resin developed as a byproduct from styrene.

Adhesion with wet, dirty and difficult stones from which the coated binder gets stripped in adverse climatic conditions. There are a number of compounds and methods by which stripping could be eliminated. The compounds can be anionic types such as soaps of heavy metal or cationic types such as quaternary ammonium salt. There are not many industries at present which manufacture these products. Some chemical industries which deal with the base material can profitably develop ancillary units to produce these compounds for use by road engineers thereby facilitating a prolonged life for road surfacings.

Promoting Utilization of Results of Research in Building

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The paper identifies the factors responsible for the slow progress in the utilization of results of research in building. It cites instances to stress the importance of detailed technical scrutiny to establish technical soundness and economic competitiveness which new techniques evolved as a result of research possess over traditional building techniques. The methodology of research follow-up and extension work with reference to utilization of building research has been discussed. The role of National Buildings Organization, coordinating research and as an agency for extension work has been briefly mentioned. Some special items of work to promote utilization of results of research in building have been putforth.

Building industry generally takes considerable time in accepting new materials, construction techniques and building methods evolved as a result of research. Such a situation does not warrant any sceptical criticism if the traditional characteristics of the industry and the technical and economic problems which it has to face in accepting any change are properly appreciated. In our country, building materials and construction practices that are prevalent today have emerged as a result of century of their usage. These have been established as proven building techniques backed by considerable knowledge and experience about their performance and efficiency.

These techniques possess some inherent advantages from the point of view of simple building technology well-understood by local craftsmen and utilization of locally available materials. Moreover, construction of buildings and houses is a long-term investment and the persons incharge would naturally like to use the materials and construction techniques which have been tested by time. Introduction of any new material or new way of construction necessarily, therefore, attracts considerable resistance from practical engineers, architects and builders.

Detailed scrutiny

Those engaged in research in building need therefore realize that utilization of results of research by the building industry is governed by the proven technical soundness and economic competitiveness which the new building techniques possess over the traditional ones. In this connection, it would be interesting to know that in all advanced countries detailed technical scrutiny is undertaken before new ideas, materials and techniques are accepted in practices by the building industry.

For example in UK, 1700 different types of non-traditional systems of construction of houses were scrutinized by a high-power committee with

the help of Building Research Station. After the serutiny only 100 systems were considered technical and economically sound. In the first few years, some subsidy was given to non-traditional type of construction to encourage their evolution. Now the subsidy has been withdrawn and about 12 techniques have survived competition.

In France, they had scrutinized 2000 different non-traditional ways of construction. Out of these 600 were approved as technically and financially sound and even out of these only less than 150 could compete with traditional methods and remained in actual business.

Methodology

The task of promoting the utilization of results of research in building calls for : (i) Research follow-up, which is action oriented research, and (ii) Extension work, which sets out successive stages for promoting the utilization of the results of research in practice.

Research follow-up

Research in building must behold the promise of its practical utilization; therefore it does not merely suffice to do research. Research should include in its scope:

(i) Full-scale laboratory trials and field trials for bringing to bear practical bias to the result.

(ii) Extension of know-how through demonstration and pilot projects, and

(iii) Dissemination of building knowledge and providing technical consultancy service.

Role of National Buildings Organization—But it may not be feasible for research worker to undertake follow-up action without impairing concentration to research work. There should be an agency solely responsible for promoting the utilization of results of building research and to bridge the gap between research and practice, thereby bringing to bear practical outlook to research workers and research outlook to practical workers. With this object in view the National Buildings Organization was established in 1954. The Organization, which is also a United Nations Regional Housing Centre of ECAFE Region, engages itself primarily with the task of coordinating building research and promoting utilization of results of research.

Research coordination—The work of coordination of research in building is of great consequence both to research and industry. Coordination is achieved by undertaking the following :

(i) Coordination and integration of building research programmes.
(ii) Identifying practical building problems of the industry.
(iii) Initiating the problems for investigation.
(iv) Farming out research shemes.
(v) Sponsoring research work — providing financial and technical assistance.
(vi) Studying and evaluating results of research, and
(vii) Presentation and dissemination of results of research.

Extension work

This entails the following action : (i) Large-scale experimental construction or pilot project work, (ii) Wide dissemination of building knowledge

in ready and intelligible form, (ii) Extension through demonstration and displays, (iv) Transformation of results of research into actual practice, and (v) Surveys to ascertain the extent of implementation,

Based on the activities of NBO some specific items of work to promote utilization of results of research in building have been given below.

Experimental construction

The Planning Commission has allocated a sum of rupees one crore for experimental housing and research during the Third Five-Year Plan period However, it has not been possible to take advantage of this as experimental projects have not been forthcoming. Before any project for experimental construction can be evolved, it is obvious that research as well as availability of its results is of paramount importance. The building industry, being lacking in this respect has not been able to undertake large-scale experimental construction.

Information Centres in State P.W.Ds. It is, therefore, essential that Information Centres in State P.W.Ds and other construction departments should be organized as receiving ends for the results of research and available building information. The existing library units in the State P.W.Ds and other construction departments should be developed with the assistance of NBO to function as well equipped Information Centres.

Building Centres. To provide impartial scientific and technical information about new building materials, construction techniques and building methods, Building Centres should be organized. There is a need to establish such Centres on regional basis as the building materials, construction techniques etc., are influenced by local conditions. The NBO is organizing one such Centre at New Delhi.

Study of building specifications. Building specifications followed by all construction departments should be collected and scrutinized with a view to finding the scope of incorporating the use of new building materials and techniques based on the research work undertaken.

Building by-laws. The building by-laws followed by municipal and other local authorities should be collected and studied with a view to introducing new ideas, building materials and construction techniques.

Assessment surveys. Through periodic surveys the extent to which results of building research are being taken advantage in practice and their impact on the technology—improvement and economy achieved should be assessed.

Evaluation work. The factors that limit the adoption of results of research should be evaluated and ways and means evolved to facilitate utilization of results of research to a greater extent.

Effective liaison. To achieve all the aforesaid objectives close coordination between research and practice should be established—liaison between the building research institutes and the building industry which the NBO has been attempting for promoting the utilization of results of research in building.

A Quick and Economical Method of Road Construction in Desert Areas

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Construction of roads in desert areas where neither any material of road construction nor even adequate quantity of water for the stabilization work is available within easy and economic leads, presents an acute problem to the road engineer.

Due to the very poor supporting power of the execssively sandy areas, sometimes it is not even possible for a human being or a cattle to walk over the surface not to speak of vehicles plying through such areas. Camel is probably the only animal which has its feet so designed by nature that it can even run easily at speed through such tracts. This is why camel is generally known as a ship of the desert and one has to employ it for passing through such areas.

With the increase of population there is a pressure on land. Good land is already thickly populated and therefore attention has to be concentrated on the exploitation of deserts and other such areas which are till now underdeveloped and unattended to. Construction of roads in such areas is no doubt the first essential requirement for proper development; as without the roads the vehicles cannot ply and men, material and machinery cannot be transported easily for necessary development. The normal conventional methods of road construction are generally not suited in such areas because of the non-availability of the materials of construction near about. Even water is very scarce and the soil being nonplastic is most unsuitable for mechanical stabilization. Cost of carriage of required quantity of conventional road materials or chemicals for stabilization of sand from long distances is very prohibitive. Moreover the construction of roads by conventional methods in such areas would consume lot of time and the desired progress of work cannot be achieved. We have therefore to look for a method by which roads can be constructed speedily without involving much cost, specially in these days of emergency.

Present practice

The present practice of moving vehicular traffic in sandy areas is the use of summer field tracks which consists of 3/8 in. iron bars suitably woven into 6–9in. mesh which can be rolled and transported in the trucks. Such tracks are of limited length for use only in emergency. After their use they are taken away. These are designed specially for particular objectives and not for regular road construction in large lengths.

Since the main objective of the road construction is to provide a load bearing surface for the vehicle to move on smoothly, the present practice of

running civilian traffic in sandy areas is to spread a 3 in. to 6 in. layer of sarkanda or any other such material over the sandy surface in order to provide the required bearing capacity and support the load of the vehicle. But this is also a very temporary measure as the loose sarkanda does not last long and has to be renewed very frequently. However the sarkanda layer can be made more duarble by binding it properly into thick layers like jacks board and laying flat on the sandy surface. But even in that case this material has its own limitations because it is generally not grown in the dry desert areas and its cartage from long distances is not economical, as huge quantity is required for covering a particular area. Where the large mileage of roads is to be constructed this material is not considered suitable. It is allright only for short stretches just to pass on the traffic to avoid traffic jams.

New method

Investigations were undertaken in the P.W.D. B&R Research Laboratory at Chandigarh to evolve a simple, quick and economical method of constructing durable tracks for vehicular traffic in desert areas; and it has been found that the bamboos which are so abundantly available in India and which possess very good flexible strength can be economically and effectively used for this purpose.

About 200 ft long, 10 ft wide and about 2 ft high embankment of non-plastic sandy soil was laid on the natural ground in the Laboratory premises and an attempt was made to drive jeep and a 3 ton truck over it. Both these vehicles got stuck up even in the first few feet length and could not move out without the help of four wheel gear. Then a bamboo network was placed over the sandy embankment and the vehicles were again taken over it. They drove very smoothly over the bamboo framework and could be stopped and restarted at any point without any difficulty and without the help of 4 wheel drive arrangement.

In the second trial the bamboo network was buried (embedded) in the sand by putting about 2–3 in. sand layer over it, and the vehicles were again driven over it. This time both the vehicles were loaded—the jeep with 10 men and the truck with 125 cu. ft of moist sand. It was found that as before both of them could be driven on this track without any difficulty and without the help of 4×4 at any point. Due to the repeated passes of the vehicles the bamboo trellis got well embedded on the sandy embankment and provided an excellent bearing area for supporting traffic loads. It has been practically found very convenient to stop and restart the truck on the bamboo tracks at any point without any difficulty.

Method of making bamboo trellis and mode of its laying on sandy subgrade

For the above study, each bamboo with 3–4 in. stem diam. was split into four pieces and made into a network of about 12×13 in. mesh by fixing with long iron nails which were then bent on the other side. While laying the frame on the sandy embankment, care was taken that bamboos running parallel to the road were kept on the lower side while the upper bamboos ran across the road. The advantage of covering with sand was to fill up any gaps below the bamboo layer and sandy track below so that the bamboos uniformly rest on sand below. Sand cover 2–3 in. on the bamboos also helps to reduce direct concentration of load on the bamboos. In spite of 6 dozen runs of loaded jeep and truck, bamboo frames remained

in tact. Further experiments to improve the arrangement are in hand.

Economic aspects

It has been estimated that according to the above arrangement cost of bamboos per 100 sq. ft, area comes to only Rs 10 and one mile long × 10 ft wide track can be made at a cost not exceeding Rs 600. Such frames can be prepared in lengths of 15–20 ft at any place and carried to the site. Laying of such tracks and joining them at ends takes very little time (a few hours) if the bamboo trellis are got made in advance. Even their making at site does not take much time.

A truck can carry a minimum of 25 bamboo trellis in one trip. If the length of each trellis is only 15 ft the 25 frames will cover a length of 375 ft or say a minimum of half furlong. In this way at the most 16 truck loads of bamboo frames can cover one mile length. Against this if bricks or any other such material is used for road construction not less than 100 trips of the truck will be needed to carry this material. The carriage cost of bamboos can be further reduced by carrying them as such and making the frames at site. In desert areas bamboos can be easily transported even on camel backs where as carriage of bitumen drums or any other conventional road material in such areas is very cumbersome.

Other uses of bamboo frames

Such an arrangement (bamboo network) is also considered suitable for service roads or dimensions in semi-marshy areas, and in dry choes. It can be also used to prevent rutsand dust nuisance on berms of the roads in busy localities or narrow roads subjected to heavy 2-way traffic. Also the sandy subgrades can be properly compacted and rolled by means of heavy road rollers by using this arrangement before laying the pavement.

Conclusion

The above preliminary trials showed that it is possible to make a track for pneumatic tyred vehicular traffic in sandy areas without much cost and loss of time by laying ready-made bamboo trellis of the type indicated above. It is also possible to run 6–8 ton road roller over such tracks. In this way stone metal wearing coat can also be laid without any other soiling material, and consolidated, semi-grouted and surface dressed to give better riding surface. Even a layer of asphalt treated sand can be laid and compacted over the bamboo layer and surface dressed as usual.

Sugar Press Mud as A Road Building Material

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Introduction

It is estimated that sugar mills employing carbonation process are producing[1] about 6–8 tons of press mud for every 100 tons of sugarcane crushed by them. As such very large quantity of this press mud, which is not yet finding any use anywhere, is being produced every year all over the country, and its disposal is a big problem for the factories. Much useful land in their proximity is being wasted by dumping this material.

Attempts have been made by the Central Building Research Institute, Roorkee[1] and Land Reclamation, Irrigation & Power Research Institute, Amritsar[2] to convert this waste material into useful building lime by burning it at suitable temperatures after moulding it into briquettes/bricks. The method developed by the Amritsar Institute is simpler as it does not involve any elaborate pressesor machinery for preparing briquettes. According to their process the press mud is mixed with optimum proportions of soil (of the type normally used for brick making) and the mixture is hand moulded into bricks which are then dried and calcined in the ordinary lime burning furnaces at a temperature of 800° to 1000°C. The product thus obtained has the properties of a good hydraulic lime suitable for use in the building construction.

Object of the present study

It has been observed during the last some years that the old roads which have been giving very satisfactory service since their construction have started giving way under increasing traffic and rising water table. Most of these have to be reconstructed with better specifications. Also the thickness of new roads has to be properly designed, as the conventional road crust (6–7 in. thickness) has been found to be most inadeqate under the present traffic conditions. It has become an essential practice to provide at least 6–12 in. thick stabilized soil sub-base which should have adequate soaked CBR value, for every road. Since the natural soil rarely shows the required soaked CBR in spite of maximum compaction it has to be mixed with some good lime or fresh portland cement to raise its soaked CBR to required degree. Alternatively the partially burnt soil from old abandoned brick kilns, where available is used. In the present investigations the engineering properties of the press mud as such have been studied to assess its suitability for use as a sub-base or base coat material for roads.

Suitability of press mud for road work

A bulk sample of the press mud was collected from the Saraswati Sugar Mills, Yamunanagar in Ambala Dist, and tested for its chemical composi-

tion, particle size grading, plasticity characteristics, CBR etc. Results are reported and discussed in the subsequent paras.

Chemical composition

Chemical composition of the press mud as found by CBRI and the Amritsar Institute and further confirmed by this Laboratory is given below:

Constituents	*Percentage*
1. CaO (Calcium oxide)	40–45
2. Loss on ignition	40–45
3. Silica	1·5–4·5
4. Insoluble matter	2–4·5
5. Iron & aluminium oxides	2–2·5
6. MgO	2–3·5

In addition to this the press mud was tested for soluble sulphates (which are detrimental for road work) content and these were found to be negligible, being less than 0·2 per cent.

Engineering properties

(a) Atterberg Limits:

LL 49·4, PL 42·6, PI 6.8

(b) Sand Content (fraction coarser then 200 mesh on wet sieving) ... 24·5%

(c) Optimum moisture required for maximum compaction ... 30%

(d) Maximum dry density at optimum moisture ... 1·4g./cc.

The usual standard methods were adopted for above tests. The press mud showed low plasticity index, and density, but high liquid limit and optimum moisture, and resembled partially burnt soils available at abandoned brick kilns in these respects.

Resistance to softening effect of water

The dry specimen blocks made by compaction at optimum moisture to the maximum density in the modified Abbot's compaction apparatus, when placed in water did not disintegrate or even become soft for a fortnight after which period they were taken out and tested for compressive strength.

Strength characteristics

The cylindrical specimen blocks of the size 2·5 in. dia. 2.5 in. high prepared in the modified Abbot's compaction apparatus at optimum moisture were dried and tested as such and after immersing in water for a fortnight. Average of 3 readings in each case showed a dry compressive strength of 156 lb./sq. in. and a wet compressive strength of about 85 lb./sq. in.

When moulded at maximum density in CBR moulds, subjected to saturation by immersing in water for 96 hr and tested for penetration resistance by CBR method the press mud showed a CBR between 15 and 20 per cent in spite of high moisture absorption of about 32 per cent. Against this the soaked CBR of most of the natural soils is hardly above 5 per cent. With the use of this material in the sub-base, therefore, the top crust thickness can be reduced by 6–8 in.

It will be seen from the above results that the press mud as such can be effectively and economically used for the construction of sub-bases of roads to make them more stable under heavy traffic and also reduce the costly hard crust thickness. Its behaviour is similar to the partially burnt clays obtained from abandoned kilns. It has also been observed that the soaked CBR of the press mud can be further improved to about 40 by mixing it with 2 or 3 per cent of freshly slaked lime or fresh portland cement.

Use of press mud as a soil stabilizer

In view of the limited availability of the press mud, and with a view to utilizing it for greater lengths, investigations were extended to see how far its addition to the natural alluvial soils of Punjab can improve their suitability for road construction Accordingly varying proportions, viz. 2·5 to 25 per cent of the press mud were mixed with the natural clayey and silty soils and necessary specimen blocks were prepared from the mixtures for further tests. It was observed that in the case of a clayey soil having a PI of 16·2 and a sand content of only 6 per cent, the addition of only 5 per cent press mud considerably improved its resistance to softening effect of water and bearing capacity. The improvement in CBR was from nil of the natural soil to about 13 per cent when only 5 per cent press mud was added. With the addition of 10 per cent press mud in such a soil, the specimen blocks (made from the resultant mixture) were completely resistant to softening effect of water and the soaked CBR value also jumped to over 30 per cent. This improvement continued with further increase in the quantity of press mud, and the CBR obtained with the addition of 20 and 25 per cent of it was 50 and 65 respectively.

When however smaller quantities of press mud, viz. 2 to 4 per cent were used in conjunction with 1 per cent freshly slaked lime by weight of soils, fairly satisfactory CBR value of over 20 per cent was obtained. The silty soil when mixed with similar proportions of press mud also gave identical results.

The above observations will show that the press mud can be used as an effective stabilizer for the natural soils in the locality and its use can therefore lead to economy in the cost of construction, besides giving better quality of roads.

Use of press mud in buildings

Preliminary experiments have shown that the mortar prepared from the press mud as such and mixed with 3 to 4 per cent bitumen cut back can be used for plastering walls. Being porous and coarse in texture the plaster does not develop any hair cracks or crazing on drying. It is highly resistant to softening and erosive action of water. It also presents

a hard granular surface pleasing to the eyes. It can be used both on internal and external walls. With the addition of bituminous cut back, the resistance of the press mud to abrasion is also greatly improved.

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Lime Surkhi-Sand Block for River Training Works

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Owing to the very short supply of cement in the country and in view of constructions activity envisaged in the Five-Year Plan, directive was issued by the Government of India and also by the respective provincial Governments not to use cement : (i) in the permanent other type of single or double storeyed buildings for walls, plastering on the inside must be done in lime mortar, wherever possible (ii) in all gravity dams, portions of dams less than 100 ft high should be built in hydraulic lime—lime surkhi or other combinations. If lime is not available efforts should be made to obtain this from the nearest area; (iii) for canal linings the committee discussed the possibility of utilizing lime or lime surkhi concrete in place of cement concrete lining. Sufficient data are not available and it is recommended to conduct full scale experiments in different parts of the country; (iv) to prepare list of sources where suitable lime and pozzolanic material are available and ; (v) to prepare tentaive standards for lime and surkhi for immediate use.

In the river training works cement concrete blocks have been invariably used for protection against river action. Considering large number of blocks required at each construction site, the cement requirements would be in very large quantity. An alternative has therefore, to be developed to make blocks without the use of cement. An investigation was taken up in the Land Reclamation, Irrigation and Power Research Institute, Punjab, Amritsar to find out alternative method without the use of cement. Cheap and low strength blocks were thus to be made with building materials other than cement.

This lime has setting property which is dependent on availability of carbon dioxide for changing it into $CaCO_3$: $Ca(OH)_2+CO_2 \rightarrow CaCO_3 + H_2O$.

In ordinary lime sand mixes the reaction between lime and sand to form calcium silicate is very little and strength gain due to this reaction will be small and no or little cohesion between the sand particles will be brought about by this change in early stages. The lime sand mix in small blocks or specimens will be more exposed in surface area with reference to its mass as compared to a big block. It will, therefore, be inevitable that small sand lime specimens will gain strength due to aeration or absorption through water between the grains in the pores and when tested are expected to show more strength per unit area as compared to bigger blocks. There might be some difference in strength due to be difference in size of block tested but in this case the margin of difference is expected to be much more as the process of carbonation affected will be much less in bigger blocks due to comparatively less exposed area. This hardening of the mix will only be at or near

the surface and in the depth below in inner parts of the blocks there will be no or little cohesion at all. This will show itself in less strength of the block and also in less durability against moisture or water when freely available. Such specimens are expected to disintegrate underwater due to little cohesion in the inner core. Only the surface layer will stand and the rest will crumble due to penetration of water which separates the particles apart.

For acceleration of the carbonation process it will be desired that the specimens or blocks be placed in carbon dioxide atmosphere and to further enhance carbonation some sort of pressure be excercised to increase the depth of penetration of carbon dioxide into the pores of blocks and also to increase the rate of reaction. This can be affected but would require (i) machinery and (ii) process of generation and stocking of CO_2 in a room or chamber where it is to be done. This would require a plant for CO_2 generation and also for pressure generation along with chamber where it is to be affected. This would increase the cost very much. Cement sand mixes might in that case be cheaper for such purpose and also easily manufactured. Moreover, the plant would be required to be set up at or near every site of its use or these be prepared and exported to destination. This transportation will further increase the cost of such blocks. In order to economize the materials should be such that they be cheap and available at site and the things be manufactured at or near the site of construction. It is on account of this that pressure carbonation is not advisable for such purposes in this state of the country's economy.

The other method may be some sort of chemical reaction which should slowly generate carbon dioxide in the mix in the presence of moisture at such a rate that lime should go on absorbing it to form $CaCO_3$. By this process carbonation of lime be affected throughout the mass of the mix and thus form a stable block and stand disintegration under water. Carbon dioxide is only generated in acid media which may be or may not be stable under water. Generation of carbon dioxide in alkaline media is not possible so this process is not very promising.

The other alternative is to add some chemical to lime in small amounts to give a binding power to the mix. Such a cheaply available material is surkhi or cinder or any other pozzolanic material which can be added in comparatively small amounts and is available at a cheap rate next to sand at site. It is on account of this that lime surkhi-sand mixes in very lean proportions were tried to prepare cheap blocks of just sufficient strength to stand the pressures and to stand disintegration due to water action. Experiments were conducted to form mixes of 1 lime to 1 sand to those up to 1 lime to 1 surkhi to 14 sand to see strength developed by them in various periods. The periods of curing were to be sufficiently long up to about six months at least so that the mix gains in strength sufficient to stand pressure and disintegration.

Six inch cube blocks were prepared of the following type of mixes: (i) Lime and sand, (ii) Lime ordinary bazar grade surkhi and sand, and (iii) Lime surkhi passing 200^2 mesh and sand.

Compressive strength of these blocks and disintegration in water was studied in all these cases. The table of compressive strength of various mixes determined is given in the Appendix. This would indicate: (i) That the lime sand mixes showed lower strengths as compared to mixes in which surkhi was used; (ii) That mixes containing surkhi passing 220^2

mesh showed higher strength than those containing bazar grade surkhi which contains a much lower quantity of particles passing 200[2] mesh ; and (iii) There was a progressive gain in the strengths of blocks containing surkhi.

The disintegration by immersion in water showed: (i) That all lime sand mortar blocks disintegrated in water within 24 hr after immersion in water alone but only a thin hardened films at surface stood this action ; (ii) The lime surkhi sand mortar mixes stood the water action even when put in water after one week from the time of their casting.

The order of the compressive strength mostly ranged from 150 p.s.i. to 250 p.s.i. in the cases studied in a period of about 3 to 4 months. The block with composition 1 lime to 1 surkhi to 14 sand could stand the disintegrating action of water and the surface hardened so as not to be scratched with hand but could not stand impact by throwing it on a corner on the ground from a height of about 5 ft. Further efforts are being made to improve these failures of these blocks to compact during handling.

Another line of investigation being persued is to find out a suitable catalyst to accelerate the rate of reaction of pozzolana with lime.

APPENDIX

DATA ON COMPRESSIVE STRENGTH OF CUBES OF 6 × 6 × 6 IN.

Sl No.	Mix	Date of casting	Date of testing	Compressive strength (lb./p.s.i.)
(1)	(2)	(3)	(4)	(5)
1.	White Lime : Surkhi (1 : 3)	13-10-1957	29-1-1958	374
2.	White Lime : Sand (1 : 3)	14-10-1957	29-1-1959	91
3.	White Lime : Sand (1 : 4)	17-10-1957	29-1-1958	93
4.	White Lime : Sand (1 : 5)	17-10-1957	31-1-1959	62
5.	White Lime : Sand (1 : 6)	18-10-1957	31-1-1958	68
6.	White Lime : Sand (1 : 7)	18-10-1957	31-1-1958	31
7.	White Lime : Sand (1 : 8)	18-10-1957	31-1-1958	Got crushed
8.	White Lime : Sand (1 : 9)	19-10-1957	31-1-1958	93
9.	White Surkhi : Sand ($1\frac{1}{2} \times 1\frac{1}{2} \times 21$)	23-10-1957	—	—
10.	White : Surkhi : Sand ($1\frac{1}{2} \times 1\frac{1}{2} \times 13\frac{1}{2}$)	23-10-1957	—	—
11.	White Lime : Surkhi : Sand (1 : 1 : 3)	24-10-1957	27-2-1858	124 p. s. i. Surkhi used passing 200 mesh
12.	White : Lime : Surkhi : Sand (1 : 1 : 3)	24-10-1957	27-2-1951	93 p. s. i. Surkhi used original
13.	White : Surkhi : Sand (1 : 1 : 7)	25-10-1957	27-2-1958	155 p. s. i. Surkhi used passing 200 mesh
14.	White : Surkhi : Sand (1 : 1 : 7)	15-10-1957	27-2-1958	155 p. s. i. Surkhi used passing 200 mesh

(1)	(2)	(3)	(4)	(5)
15.	White Lime : Surkhi : Sand (1 : 1 : 6)	28-10-1958	27-2-1958	187 p. s. i. Surkhi used passing 200 mesh
16.	White Lime : Surkhi : Sand (1 : 1 : 6)	28-10-1958	28-2-1958	124 p. s. i. Surkhi used original
17.	White Lime : Surkhi : Sand (1 : 1 : 5)	28-10-1858	27-2-1958	187 p. s. i. Surkhi used passing 200 mesh
18.	White Lime : Surkhi : Sand (1 : 1 : 5)	28-10-1958	27-2-1958	187 p. s. i. Surkhi used original
19.	White Lime : Surkhi : Sand (1 : 1 : 4)	30-10-1958	27-2-1958	218 p. s. i. Surkhi used passing 200 mesh
20.	White Lime : Surkhi : Sand (1 : 1 : 4)	30-10-1958	27-2-1958	155 p. s. i. Surkhi
21.	White Lime : Surkhi : Sand (1 : 1 : 2)	1-11-1958	27-2-1959	249 p. s. i. Surkhs used passing 200 mesh
22.	White Lime : Surkhi : Sand (1 : 1 : 2)	1-11-1958	27-2-1958	187 p. s. i. Surkhi used original

A Study of Effect of Addition of Lime Putty and Lime Putty Surkhi Combinations on Cement Mortars for Use in Masonry Structures

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Introduction

Cement is prepared from fused clinker and consequently its grain is very hard. The grinding operation can only take fineness to a certain limit beyond which it is uneconomical. The cement powder thus produced though sufficiently fine still is coarse enough for purposes of penetration into the fine pores of coarse and fine aggregates to effect a good bond between the cement and aggregate particles. The cement being comparatively coarse in particle size is harsh to work with. In order to improve its workability and plasticity and its power of bond with brick or stone particularly for masonry work certain additives are used. These additives are usually very fine in particle size. For masonry works the workability and plasticity are very important and cement as such is not able to meet these requirements satisfactorily. Consequently cements used for masonry work are either specially prepared by addition of certain materials at manufacturing plant or those materials are added at the site of work at the time of preparation of the mixes. The better workability and plasticity of masonry cement are obtained by combination of portland cement with substances such as natural cements, granulated slag, hydrated lime, calcium and aluminium stearates paraffin oil, colloidal clay and diatomaceous earths. Whereas other materials are not easily and economically available, hydrated lime is a very common material and easily available. The fineness of hydrated lime is much higher as compared to fineness of portland cement. Hydrated lime is usually added to improve workability and plasticity of portland cement and also to effect improvement in bond. In order to study the effect of addition of lime on the properties of cement sand mixes various amounts of hydrated lime were added to portland cement and strength determinations made at various intervals of time of curing.

Experimental

Hydrated lime sieved to pass through 200[2] mesh sieve to remove any unhydrated particles was prepared in the form of a lime putty and used in cement sand mixes. The cement sand mixes of 1 cement to 2, 3, 4, 5, 6, and 7 sand parts respectively were prepared without any lime putty added to them. Each mix was then prepared by replacing cement with lime putty by weight of hydrated lime by 1, 2.5, 5, 7.5 and 10 per cent respectively. The strength was determined after 3 days, 7 days, 28 days, 3 months and 6 months of water curing. Curves were then drawn separately for 1 : 2, 1 : 3, 1 : 4, 1 : 5, 1 : 6, and 1 : 7 cement sand mixes in which lime putty has been

used in percentages given above in each case and without its use. Two types of curves were drawn : (i) in which the strength was plotted with increasing periods of curing separately for each amount of lime putty in the mix and (ii) in which the strength for each period of curing for mix was plotted against increasing amount of lime putty in the mix.

The following inferences were drawn :

(1) The strength of a mix, i.e. 1 : 2, 1 : 3, 1 : 4, 1 : 5, 1 : 6 and 1 : 7 decreases as the amount of lime putty is increased in them.

(2) The decrease in strength with increasing amount of lime putty ir a mix was noticeable at all ages of curing periods studied.

(3) The fall in strength was small for each of the mixes with increasing amount of lime putty in the mix.

(4) As the mix got leaner, the effect of increasing amount of lime putty in reduction of strength after 6 months of curing was lessened.

It was considered of interest to associate a pozzolana with lime putty and than see its effect on cement mortar mixes. The lime putty and a local surkhi ground to pass 100^2 mesh sieve were mixed together in the ratio of 1 lime putty to 2 surkhi so that lime could be fully neutralized by surkhi in course of time and that any ill effects due to use of lime may be eliminated. The lime thus fixed with surkhi was used in replacing cement in amounts of 1, 2.5, 5, 10, 15, 20, and 25 per cent in 1 cement to 2,3,4,5 and 6 sand parts respectively by weight. The specimens thus prepared were cured in water for 3 days, 7 days, 28 days, 3 months and 6 months respectively. The strength of these determined, and is plotted in the form of curves in two different manners as already given earlier in the text for each of the mixes separately.

The following inferences were drawn :

(1) The strength of a mix, i.e. 1 : 2, 1 : 3, 1 : 4, 1 : 5 and 1 : 6 decreases as the amount of lime putty surkhi combinations increased in them.

(2) The decrease in strength with increasing amount of lime putty surkhi combination in a mix was noticeable at all stages of curing periods studied.

(3) The fall in strength was not very large in each respective mix with increasing amounts of lime putty surkhi combination in the mix after six months. It was considerable in earlier stages.

It will be seen that similar inferences were drawn when lime putty alone or lime putty surkhi combination was used in the mix. However, it was seen that the workability and plasticity was better with lime putty alone mixed with cement then when surkhi lime putty combination was used with cement.

Conclusion

For masonry works hydrated lime could be used in combination with cement up to 10 per cent to improve workability, plasticity and bond. The improvement in bond with brick or stone in masonry will cover any loss in strength of the mortar.

Significance and Scope of Timber Engineering For Economic Development of Construction Industry

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Heavy constructional programmes in our industrial development plans have drawn attention of the Government as well as the public to the need for rational and economical utilization of timber for construction industry through research, design and constructional solutsons. Therefore, in this context, some rational solution involving economic timber structural construction suitable for factory heds, residential buildings, military structures, and our other national projects must be found out.

The objective of this paper is to bring home to the industry the results of various research data, design methods, fabrication know-how and practical implementation of timber as a structural material, as found out in the Timber Engineering Branch, FRI. Such research work embraces the industry, forestry, defence, agriculture and needs to be adopted by the industrialists, foresters, defence organizations and agriculturists alike.

A recent survey revealed that as many as 85 per cent of structural roof frames fall within the span-range of 3 to 20 metres. This comprises industrial sheds, military structures and residential buildings etc. The usual practice is to go in for RCC and steel frame construction; where timber is used, it is also according to the primitive and irrational construction methods as also designs using long lengths and large sections of the primary species, e.g. teak, sal, deodar, sissoo, etc. which not only increases the overall cost of construction, but also effect wastage of material. Time has come when the whole concept of structural timber engineering needs revision and change. Long lengths and large sections of primary timber species should give place to short lengths and small dimensions of secondary species of timber locally available at economical rates. Similarly thick gusset plates, bolts and nuts should be replaced by ordinary wire nails available everywhere. Such change and revision in the utility of timber as a building material will result in modernization of engineering curriculum consistent with the changing needs of the country, new outlooks, recent progress in research and new technique in modern Timber Engineering. The re-casting of the technique should take into account the future anticipated developments apart from the developments made in the field so far.

This paper deals with the significance and scope of Timber Engineering in the economic development of Construction Industry as also the various problems confronted and their solutions found out with emphasis on extensive

utilization of small dimensioned stock with improved design methods, such that the industrialist, architect, designer and builder can all share a common interest in the quaitly and quantity of timber grown, harvested and utilized.

Availability of structural timber

The present position of availability of structural timber is rather not encouraging. It has been estimated that as compared to the abundant number of secondary species, structural timbers form only 25 per cent. The conversion yield at the saw mills is also very low—only 50 to 60 per cent. It is thus imperative the the various techniques involved in the modern Timber Designs and Construction should be employed to use small dimensioned stock of secondary species jointed by means of ordinary wire nails.

In modern timber engineering designs, use is however made of the lower-cost secondary species of timber not hitherto taken advantage of in structural construction work. Most of these secondary species can be improved in their durability and dimensional stability after seasoning and chemical preservation.

Recent investigations have revealed that modern timber engineering technique does not require large sizes and long lengths of timber for structural purposes. With the present day practice, the short length small dimensioned timber received as a byproduct from the off-cuts, slabs and rejections associated with the conversion of logs etc. is being used for various purposes including as a fuel wood. This is a sheer waste of material. Such product can economically be used in modern timber engineering technique for structural purposes.

The main phases of design and construction of timber structures are broadly based on the three heads:

(i) Selection of a suitable species of timber for specific job in question.

(ii) Scientific design of component parts of the structure, i.e. members and joints.

(iii) Fabrication and erection of structural units in position.

Selection of suitable species

In order to obtain a sound and economical structure, the following factors need careful consideration: Strength, durability, dimensional stability and architectural beauty are the essential qualities required of any structural wood. Any species of wood possessing these qualities either in its natural form or after suitable chemical treatment, can suitably be put up for structural purposes.

The so-called primary species of timber, e.g. teak, sal, deodar, sissoo etc. are naturally resistant to insects and rot for a considerable period. It is for this reason that such species are widely used. The other secondary species when properly seasoned and affectively treated with certain chemicals are also very resistant to insects and decay. It has been found that the structures made from small dimensioned stock of these secondary species

Table 1—Choice of timber species* according to span limits and strength limitations

Small spans (3 to 6 metres)		Medium spans (7 to 12 metres)		Large spans (13 to 30 metres)	
E>800,000 but <1,400,000 lb./) ft.<1200 lb/.sq. in. sq. in.		E 1,400,000 1, 800,00 lb./sq ft.<1750 lb/sq. in in.		E 1800,000 lb./)sq. in. ft.<2600 lb./sq. in.	
Permanent structures	Temporary structures	Permanent structures	Temporary structures	Permanent structures	Temporary structures
32	7	24	10	2	12
Species	species	species	species	species	species

E = Modulus of Elasticity in lb. per sq. inch.

ft = Extreme fibre stree in bending and tension along grain in lb./sq. in.

*For details of species refer: Rational Classification of Structural Timbers, their choice and economy as applied to modern Timber Engineering technique

would give longer service if the same care is given to them, as is given to the steel and concrete structures*.

Rational grouping of timber

India is traditionally rich in its forest wealth and it is estimated that the number of species of timber growing in India run into four figures; Generalization and standardization of such a large number of species is rather impracticable. However, it is a general feeling and requirement that some sort of grouping of these species into a definite number of strength groups is absolutely essential in order to bring out standard type of designs of various structural components e.g. beams, purlins, trusses, columns etc. such that these designs are readily utilized without any further calculations in the Design Office.

The Timber Engineering Branch, FRI after careful consideration of the various mechanical strength properties of wood influencing the design etc. have classified various species under 'Ordinary', 'Standard' and 'Super groups' and these are recommended for small, medium and large spans respectively, defined as under :

(1) Small spans up to 6 metres

(2) Medium spans > 6 metres but < 12 metres

(3) Large spans > 12 metres

It has been found that out of the many timbers grown in India, only 87 species are suitable for structural purposes. A gist of the rational grouping as framed, is given in Table 1.

*Note:

(a) Cost of pre-cut sizes of secondary timber (untreated) from market according to sizes required in design work varies at an average rate of Rs 5 to 9 per cu. ft.

(b) Cost of seasoning these cut sizes varies from Re 0.50 to Re 1.00 per cu. ft depending on type and size of species.

(c) Cost of treatment for these cut sizes varies from Re 1.00 to 1.50 per cu. ft for use in inside location like trusses, refters, purlins etc.

(d) Cost of labour (semi-skilled for fabrication of modern nailed trussesfr om 3 m. up to 20 m. span varies from Rs 3 to 4 per cu. ft. of wood used.

(e) Wastage of timber in fabrication comes to 10 to 12 per cent after getting the pre-cut sizes from market.

Design of members and their tests

Timber is an isotropic material and as such the design has to be prepared depending upon the safe working stresses of the species experimentally determined. As such the structural section would vary from species to species, taking into consideration the load as mentioned in the I.S. Code of Practice (I.S. 883 : 1961 revised).

The trusses designed and fabricated are subjected to actual tests to destruction as well as to long-term proof tests when their relative deflections are noted. The various destructive tests on different span timber trusses have shown that they have taken 3 to 7 times the design load and as such the overall factor of safety varies from 3 to 7.

Economies of nailed trusses

A simple way of jointing different pieces of timber is through nails which have been found quite stiff and economical fastners. Besides, timber waste is a minimum. Fabrication and erection methods are not at all complicated and require only ordinary carpentry tools like the saw and the hammer to do the entire job. Mass cutting methods can well be employed to reduce the fabrication period. It has been ascertained that the nails raise the jointing efficiency to as much as 50 per cent as compared to 25 per cent in the case of conventional type carpentry-jointed timber roof trusses using long lengths and thick sections.

Quite a number of timber trusses through modern Timber Engineering technique have been fabricated and erected throughout the country and on the basis of these economies worked out. Tables 2 to 4 show the relative economies achieved through fabrication and erection of different span timber trusses.

Special type of timber trusses for chemical industries

To meet with the requirement of chemical industries it is now possible to deliver ready designs of all-wood trusses from 3 to 20 metres, which range of span is generally come across by the chemical and other industries. This obviates the chemical action of acids and other chemicals manufactured in such industries. The conventional practice is to use steel trusses (in the absence of timber trusses) which are awefully pitted away in a very short period of 2 to 4 years and need replacement.

Development of industries which are not yet fully organized and developed

Timber Engineering industry is still in its infancy in our country, and needs encouragement and organization. Although it has not yet fully developed, yet there is enormous scope for it and it is high time that efforts should be made to popularize the same.

Broadly speaking, timber engineering industries could be split up into two types, viz. large scale industries and small scale industries.

Large scale industries would deliver ready-made components of timber for specific use (i.e. roof trusses, purlins rafters, beams, door and window frames and shutters etc.) from the available side slabs, defective logs, short log etc. to produce the following structural sizes:

(i) Thickness 1·5 to 5 cm., (ii) Widths 4 to 15 cm., and (iii) Lengths up to 2 metres.

Table 2—Quantities of timber and nails required for trusses and purlins, etc. per 100 sq. ft of ground area (covered) for different spans

Span	Timber for: Trusses (cu.ft)	Purlins (cu.ft)	Total (cu.ft)	Nails (lb.)
(1)	(2)	(3)	(4)	(5)
RESIDENTIAL TRUSSES				
3 METRES SPAN				
(a) Light weight roofing using C.G.I. sheets with ceiling	1.238	7.06	8.298	1.9
(b) Medium weight roofing using S.C. sheets with ceiling	1.25	7.886	9.136	1.94
(c) Heavy weight roofing using earthen tiles with ceiling	1.60	15.69	17.29	4.22
4 METRES SPAN				
(a) Light weight roofing using C.G.I. sheets with ceiling	1.225	6.59	7.815	1.115
(b) Medium weight roofing using A.C. sheets with ceiling	1.29	7.92	9.21	1.91
(c) Heavy weight roofing using earthen tiles with ceiling	2.71	10.4	13.11	5.81
5 METRES SPAN				
(a) Light weight roofing using C.G.I sheets with ceiling	1.3127	5.85	7.1627	1.58
(b) Medium weight roofing using A.C. sheets with ceiling	1.448	6.86	8.308	1.58
(c) Heavy weight roofing using earthen tiles with celing	2.58	11.90	14.78	3.24
6 METRES SPAN				
(a) Light weight roofing using C.G.I. sheets with ceiling	1.832	5.415	7.247	2.982
(b) Medium weight roofing using A.C. sheets with ceiling	1.832	5.76	7.592	2.982
(c) Heavy weight roofing using earthen tiles with ceiling	3.636	9.07	12.706	8.08

INDUSTRIAL AND MILITARY STRUCTURES

Span	Timber for: Trusses (cu.ft)	Purlins (cu.ft)	Nails for trusses in (lb.)	Remarks
9 Metres	2.80	2.4	1.7	
10 Metres	2.94	2.8	3.2	
11 Metres	2.50	3.1	2.3	
50 ft 3 in.	5.5	2.9	5.2	Designed for National Grain Godowns
60 ft 0 in.	3.7	2.3	5.0	Constructed at Ballarshah, Dhanu and Paratwada (under construction)

NOTE — The above designs are based on Wind Zone III, vide I.S. Code of Practice No. 875 : 1957

Table 3—Statement of comparative costs

Type of Construction	Covered area (sq.ft)	Cost (Rs)	Rate per sq. ft of covered area (Rs)
(1)	(2)	(3)	(4)
I. FOR A SPAN OF 20 FT			
1. Prefabricated tubular trusses supported on steel stanchions	1000	2400	2.40
2. King post trusses supported on masonry pillars	1000	780	0.78
3. Nailed timber trusses supported on masonry pillars	1000	720	0.72
II. FOR A SPAN OF 30 FT			
1. Prefabricated tubular construction	—	—	2.75
2. Prefabricated steel sections supported by steel stanchions	1600	3700	2.47
3. Queen post truss supported on masonry pillars	1500	2100	1.40
4. Nailed timber truss supported on masonry pillars	1500	1520	1.00 Plinth area rates
III. FOR A SPAN OF 44 FT			
1. Prefabricated steel section with steel stanchions	2200	6400	2.90
2. Queen post truss on masonry pillars	2200	6400	2.90
3. Nailed timber truss	2200	2500	1.13
IV. FOR A SPAN OF 41 FT EFFECTIVE			
(From actual construction at Dehra Dun for Nari Shilp Mandir)			
1. Cost of one modern type nail-jointed timber truss including material and labour	—	160	—
2. Cost of one steel truss including material and labour (cost of steel at controlled rates)	—	400	—
V. FOR A 60 FT SPAN ROOF TRUSS			
(2,3 & 4 from actual construction at Ballarshah and Dhanu, excluding roof covering material)			
1. Steel trusses with steel purlins supported over R.C.C. pillars	—	—	4.82
2. Timber trusses with timber purlins supported over R.C.C. pillars	—	—	2.93
3. Timber trusses with timber purlins supported on masonry pillars	2.47	—	2.47
4. Timber trusses and timber purlins supported over hollow columns resting on dwarf concrete pillars	—	—	2.41

Table 4—Statement of comparative costs : new vs. old truss designs from existing construction works at FRI Ballarshah, Dhanu & Meerut

Span of truss	Spacing of trusses	Timber per truss (cu.ft)	Timber for per day of purlins (cu.ft)	Nail for one truss (lb.)	Bolts & flats (lb.)	Approx. cost of one unit in (Rs)	Rate per sq. ft of ground area in (Rs)	Net saving sq. ft in new type designs in (Rs)	Saving
25 ft New type design	12′-0″	4.40	15.6	9.0	—	266.75	0.89	0.61	40.67
25 ft Old type design at New IFC Building	10′-0″	10.70	16.66	—	48.3	373.68	1.50	—	—
33 ft New type for proposed Central Library Building	12′-0″	11.25	15.00	15.0	—	352.50	0.89	0.73	54.06
33 ft 3 in. Old type at new IFC Building	14′-0″	25.50	31.0	—	69.0	759.75	1.62	—	—
50 ft 3 in. New type for foodgrains godowns	9′-3″	26.00	13.50	25.0	—	532.25	1.14	1.39	54.94
50 ft 0 in. Iron truss for new type IFC Building	10′-0″	Angle Iron & Flat 29.25 md.	7.80 md.	—	0.75	1267.00	2.53	—	—
60 ft 0 in Timber truss for integrated shed at Ballarshah	10′-0″	26.0	12.00	29.0	—	1002.00	1.67	1.13	40.0
60 ft 0 in Iron truss for fabrication shop at Meerut	10′-0″	Angle Iron Flat & Bolts etc. 0.85 M/Ton	0.55 M/Ton	—	—	1680.00	2.80	—	—

For comparison the following rates are taken at Dehra Dun : Finished timber @ Rs 10 cu.ft, Nails @ Re 0.75/lb., Hardware @ Rs 30/md. at controlled rates. Bolts & nuts @ Re 0.50/ lb. Fabrication charges for timber truss @ Rs.3/cu.ft Fabrication charges for steel truss @ Rs 3.50/md.

Rates for Ballarshah & Dhanu : Ti mber teak @ Rs 20/cu.ft Nails & bolts @ Rs 1.50/lb., Fabrication charges & erection @ Rs 5.00 cu.ft.
Rates for Meerut : Steel @ Rs 1000/ M.ton. Fabrication & erection charges Rs 200 M. ton.

For this purpose properly seasoned and chemically preserved timber in small sizes can be used to fabricate the structural components in small wood workshop after planning and assembling the units.

Compared to the conventional types of timber roof trusses etc. the approximate conservation expected in timber is more than 50 per cent and that in steel is more than 90 per cent.

Capital required for one such unit would cost not more than Rs 30,000 excluding seasoning and preservation plants.

Small scale industries or cottage industries should be located in areas where forest wastages, e.g. branch wood and thinnings etc. can easily be collected either by manual labour or with the help of carts etc. Each unit shall possess one portable saw mill and other ancillary equipment required for a small wood workshop.

Small scale industries are expected to fabricate and deliver structural components for assembling in the structural frames. These industries shall employ the villagers in a profitable profession and considerably improve the utilization and conservation side of our timber wealth.

Capital required for one such unit would be Rs 5,000 only for carpentry tools and other equipment etc.

Both the above schemes employ ordinary third class carpenters under the supervision and guidance of a mistry incharge and as such can conveniently be adopted and usefully employed in projects.

Conclusion

New truss designs, developed at the Timber Engineering Branch, Forest Research Institute have been tested and found suitable for both temporary and permanent structures. The nailed wood construction is economic, adaptable, strong and stiff. It supports static and dynamic loads equally well.

Advantages obtained from the new designs are:

(1) Small dimensioned short length timber pieces can safely be used for considerably big spans

(2) Ordinary wire nails for structural joints of large span roof frames are utilized

(3) Overall economy and ease of construction is effected through modern Timber Engineering technique

(4) Superiority of wood over all other structural material on the weight for weight basis is confirmed

(5) Employment of semi-skilled artisons under a competent carpenter-mistry incharge is feasible

(6) Seasoning is easier and is affected in reasonably short time due to use of small sections of timber. Seasoning degrade and seasoning defects are minimized with the use of small-dimensioned stock

(7) Chemical treatment is effective and thorough due to the use of small dimensioned pieces, and

(8) A better grade of lumber can be made available due to reduction of defects by cutting away and rejecting the portion of defects and utilizing the accepted portions of short length small dimensioned pieces to form into long lengths by modern timber engineering joint technique.

From the aforesaid discussion it may be concluded that short length small dimensioned timbers from secondary species are the most logical material to be used for structural purposes. Besides, it is high time that the conservation of timber be made at this stage when some of the primary species of timber are already becoming extinct. A proper understanding of physical and mechanical properties of wood, an intelligent use of modern timber engineering methods and rational selection of timber species will bring the modern timber engineering technique to its desired position in our future development schemes for economical roofs of our industrial, residential and military structures.

Price : Rs. 7.00 Sh. 14/- $ 2.00